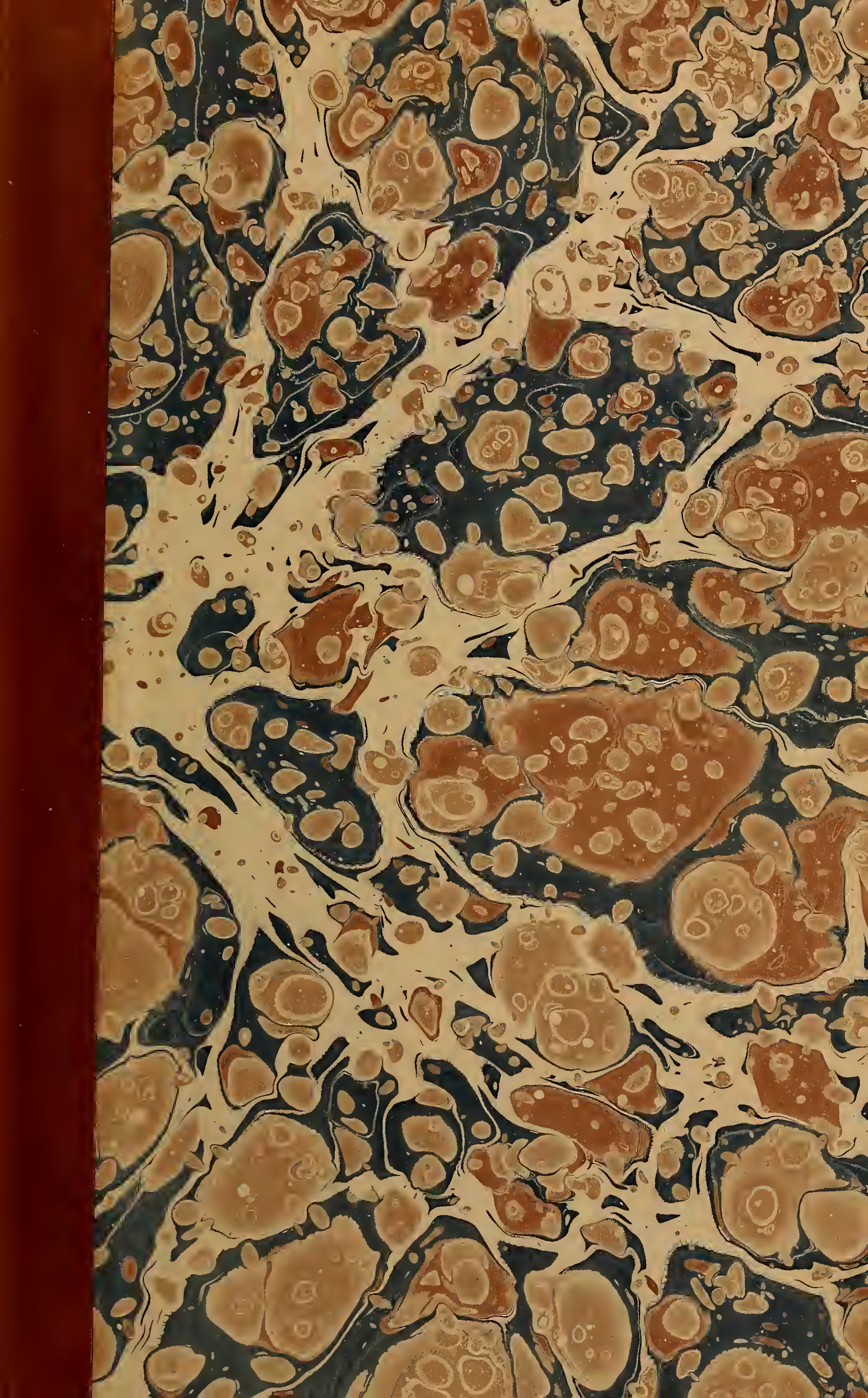

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From the Author

PHILOSOPHICAL
ESSAYS

On the following Subjects:

I.

On the Principles of MECHANICS.

II.

On the Aſcent of VAPOURS, the
Formation of CLOUDS, RAIN
and DEW, and on ſeveral other
Phænomena of AIR and WATER.

III.

Obſervations and Conjectures on the
Nature of the AURORA BOREALIS,
and the Tails of COMETS.

BY

HUGH HAMILTON, D.D. F.R.S.
Profeſſor of Philoſophy in the Univerſity of Dublin.

DUBLIN:
Printed by W. SLEATER, at POPE'S HEAD,
on CORK-HILL. 1766.

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Hon. Chas. F. Adams,
July 2, 1891.

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TO

The Right Honourable

FRANCIS ANDREWS, L.L.D.

PROVOST of TRINITY COLLEGE, DUBLIN,

AND

One of his Majeſty's Moſt Honourable PRIVY COUNCIL,

The following

ESSAYS

Are humbly Inſcribed,

By his moſt faithful

And obedient Servant,

The AUTHOR.

AN

ESSAY

ON THE

PRINCIPLES of MECHANICS.

AN ESSAY ON The Principles of Mechanics.*

IN this Eſſay I mean only to offer ſome Remarks on the Methods that have been commonly uſed in treating of thoſe Engines that are called the Mechanic Powers; and to give an Account of the Principles on which, I think, we may beſt explain their Nature and Manner of Acting.

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* This Eſſay was read at a Meeting of the Royal Society on the 21ſt and 28th of *April*, 1763, communicated in a Letter dated 13 *July*, 1762, to *Matthew Raper*, Eſq; F. R. S. of *Thorley*, in *Hertfordſhire*. *Vide* Phil. Tranſactions. Vol. LIII.

The many uſeful Inſtruments that have been ſo ingeniouſly invented, and ſo ſucceſsfully executed, and the great Perfection to which the Mechanic Arts are now arrived, would naturally incline one to think that the true Principles on which the Efficacy and Operations of the ſeveral Machines depend, muſt long ſince have been accurately explained. But this is by no Means a neceſſary Inference; for, however Men may differ in their Opinions about the true Method of accounting for the Effects of the ſeveral Machines, yet the practical Principles of Mechanics are ſo perfectly known by Experience and Obſervation, that the Artiſt is thereby enabled to contrive and adjuſt the movements of his Engines with as much certainty and ſucceſs as he could do, were he thoroughly acquainted with the Laws of Motion, from which theſe Principles may be ultimately derived. However, tho' an enquiry into the true Method of deducing the practical Principles of Mechanics from the Laws of Motion, ſhould perhaps not contribute much to promote the Progreſs of the Mechanic Arts, yet it is an Enquiry in itſelf uſeful, and in ſome Meaſure neceſſary; for, ſince late Authors have uſed very different Methods of treating this Subject, it may be ſuppoſed that no one Method has been looked upon as ſatisfactory and unexceptionable. I ſhould therefore wiſh to contribute towards having this Subject treated with more accuracy than has been hitherto done.

The moſt general and remarkable theorem in Mechanics certainly is this, " That when two " Weights, by means of a Machine counterpoiſe " each other, and are then made to move toge- " ther, their Quantities of Motion will be equal". Now an *Æquilibrium* always accompanying this equality of Motions, bears ſuch a reſemblance to the Caſe wherein two moving Bodies ſtop each other, when they meet together with equal Quantities of Motion; that Doctor *Wallis*, and after him moſt of the late Writers, have thought the Cauſe of an *Æquilibrium* in the ſeveral Machines, might be immediately aſſigned; by ſaying, That ſince one Body cannot produce in another a Quantity of Motion equal to its own, without loſing its own at the ſame Time; two heavy Bodies, counteracting each other by means of a Machine muſt continue at reſt, when they are ſo circumſtanced that one cannot deſcend, without cauſing the other to aſcend, at the ſame Time, and with the ſame Quantity of Motion, and therefore two heavy Bodies in ſuch Caſes muſt always counterbalance each other. Now this Argument would be a juſt one, if it could properly be ſaid that the Motion of the aſcending Body was produced by that of the deſcending one; but, ſince the Bodies are ſo connected that one cannot poſſibly begin to move before the other, I apprehend, that, if the Bodies are ſuppoſed to move, it cannot be ſaid that the Motion of one is produced by that of the other:

ſince whatever Force is ſuppoſed to move one muſt be the immediate Cauſe of Motion in the other alſo; that is, both their Motions muſt be ſimultaneous Effects of the ſame Cauſe, juſt as if the two Bodies were really but one. And therefore if I was to ſuppoſe, in this Caſe, that the ſuperior Weight of the heavier Body (which may be in itſelf much more than able to ſuſtain the lighter) ſhould overcome the Weight of the lighter and produce equal Motions in both Bodies; I do not think that from thence I could be reduced to the Abſurdity of ſuppoſing, that one Body, by its Motion, might produce in another a Motion equal to its own, and yet not loſe its own at the ſame time. But thoſe who argue from the equality of Motions on this Occaſion ſay further, that, ſince the two Bodies muſt have equal Motions when they do move, they muſt have equal Endeavours to move even whilſt they are at reſt, and therefore theſe Endeavours to move, being equal and contrary, muſt deſtroy each other, and the Bodies muſt continue at reſt, and conſequently balance each other. In Anſwer to this I muſt obſerve, that the abſolute Force with which a heavy Body endeavours to deſcend from a State of reſt can only be proportionable to its Weight; and therefore I think it is neceſſary that ſome Cauſe ſhould be aſſigned why (for Inſtance in the Lever) the endeavour of one Pound to deſcend ſhall be equal to that of four Pounds; and eſpecially as the *Fulcrum* on which both weights act requires no greater Force to ſupport it than that of five Pounds.

From theſe Conſiderations I infer, that the Reaſon why very unequal Weights may balance each other, ſhould be aſſigned not from their having equal *momenta* when made to move together, but by proving *a priori* without conſidering their Motions, that either the Reaction of the fixed Parts of the Machine, or ſome other Cauſe, ſo far takes off from the Weight of the heavier Body as to leave it only juſt able to ſupport the lighter. However, as this Equality of *momenta* which always accompanies an *Æquilibrium*, affords a very elegant Theorem, it ought to be taken Notice of in every Treatiſe of Mechanics, and may ſerve as an *Index* of an *Æquilibrium*. But I would not have it applied to a Purpoſe for which it is unfit; as it has been in another Inſtance by Doctor *Keil*, who from thence gives the Reaſon why Water ſtands at the ſame height in a narrow Tube and a wide Veſſel with which it communicates. And an Argument of the ſame kind is applied ſtill more improperly by Dr. *Rutherforth* and others, to ſhew why a drop of Water included in a ſmall conical Tube will move towards the narrower End; and yet the true Ways of accounting for both theſe Phænomena are extremely obvious and eaſy.

The ſimple Mechanic Powers are uſually reckoned ſix, the Lever, Axle and Wheel, Pully, Wedge, inclined Plane, and Screw. The only Method I have met with of explaining the Nature of theſe Machines upon one and the ſame Principle, is that which I juſt now examined; and, as that appears to me unſatisfactory, I ſhall conſider the Nature of each Machine ſeparately in the Order I have ſet them down.

The Lever is ſaid to be a right Line, inflexible and void of weight. Its fundamental Property is this; when any two Forces act againſt each other on the Arms of a Lever, they will continue in *Æquilibrio*, if their Quantities are inverſely as the Diſtances between the Points to which they are applied and the Point round which the Lever turns, which Point is called the *Fulcrum* or Prop.

Several Methods have been uſed, by different Authors, to prove, that this Property muſt neceſſarily belong to the Lever. We find, in the Works of *Archimedes*, a Proof brought for this Purpoſe, which has ſince been made uſe of by ſeveral Writers of Mechanics; who, I find, have ſomewhat altered the Form of his Argument, the Subſtance of which is generally expreſſed as follows, —" When a Cylinder of any uniform Matter is " ſupported at its middle Point, it will continue at reſt; for all the Parts on one Side muſt balance thoſe on the other, being exactly equal to them both in weight and ſituation, ſo that the whole weight of this Cylinder may be looked upon as acting on the middle Point on which it is ſupported. From whence it follows, that the Weight of ſuch a Cylinder will act upon whatever ſupports it, in the ſame Manner as it would do if it was all contracted into the middle Point of its Axis. If therefore we ſuppoſe the Cylinder to be diſtinguiſhed into two unequal Cylinders or Segments, the Diſtances between the midde Points of thoſe Segments and the Middle of the whole Cylinder will be inverſely as the lengths of the Segments; that is, inverſely as their Weights: But, as it was ſaid above, the weight of each Cylinder acts in the ſame Manner as it would do if contracted into the middle Point of its Axis; and therefore if the Weights of thoſe Cylinders be contracted into theſe Points, they will continue to ſupport each other as before. And thence it is concluded, that any two Weights acting againſt each other on a Line ſuſtained at a fixed point, will counterpoiſe one another, when they are inverſely as the Diſtances of the Points on which they act, from the Point on which the Line reſts.” To this A~~gree~~rgument there ſeems to be a manifeſt Objection; for, when the whole Cylinder is diſtinguiſhed into two Segments, part of the Weight of the greater

Segment acts on the ſame Side of the *Fulcrum* with the leſſer Segment; and therefore when the whole Weight of the greater Segment is contracted into its middle Point on one Side of the Fulcram, and acts all of it againſt the leſſer Segment, it requires at leaſt ſome Proof to ſhew, that this contracted Weight will be balanced by the Weight of the leſſer Segment. Mr. *Hugens*, in his *Miſcellaneous Obſervations on Mechanics*, takes Notice of this Objection to *Archimedes*'s Method, which, he ſays, ſeveral Mathematicians had endeavoured to remove, but without Succeſs. He therefore, inſtead of this Method, propoſed one of his own, which depends on a *Poſtulatum* that he uſes in common with *Archimedes*, and which I think ought not to be granted on this Occaſion; it is this: "When equal Bodies are placed on the Arms of a "Lever, the one which is furtheſt from the *Fulcrum* "will prevail and raiſe the other up." Now this is taking it for granted, in other Words, that a ſmall Weight placed further from the *Fulcrum* will ſupport or raiſe a greater one. The Cauſe and Reaſon of which Fact muſt be derived from the Demonſtration that follows, and therefore this Demonſtration ought not to be founded on the ſuppoſed ſelf-evidence of what is partly the Thing to be proved: But perhaps it may be ſaid, that the *Poſtulatum* may be granted merely on this Account; That the Center of Gravity of the two Bodies (which in this Caſe is the middle Point between them)

them) is not ſuſtained; and therefore the Body which is on the ſame Side of the *Fulcrum* with the Center of Gravity will deſcend.

In Anſwer to which I muſt obſerve, that this Property, which the Center of Gravity has of deſcending, when not placed directly above or below the Point of Suſpenſion, cannot be proved to belong to it in any Caſe, nor can we even ſhew that there is only one Center of Gravity between two Bodies joined by a right Line, until it is proved in general that the Center of Gravity of any two Bodies is a Point ſo placed between them that their Diſtances from it are inverſely as their Weights: but this in effect includes the principal Property of the Lever, which therefore cannot be proved from any previous Suppoſition, that the Center of Gravity will deſcend, even when the Bodies are equal, and we know it is the middle Point between them.

I muſt now proceed to conſider what Sir *Iſaac Newton* hath delivered on this Subject in his *Principia*, after the 2d cor. to the 3d Law of Motion which Dr. *Clarke* (in his Notes on *Rohault*) and all the ſubſequent Writers, have quoted as an elegant Proof of the Property of the Lever; and therefore what appears to me at preſent an Objection to this Proof I ſhall mention with great diffidence, and in hopes of being ſet right if I am wrong. Sir *Iſaac* ſuppoſes two Weights, as A and P. Fig. 1. to hang by Threads, from the Points M and N. in a Wheel or circular Plane Perpendicular to the Horizon and Movable about its Center O; and then propoſes to determine the Forces with which theſe Weights act to turn the Wheel round its Center. In order to do this, he ſuppoſes that it is indifferent from what Points in the perpendicular Lines M A and N P the Weights are hung, for that they will ſtill have the ſame Power to turn the Wheel about its Center. His Words are: "*Quoniam nil* "*refert utrum filorum puncta K, L, D, affixa ſint* "*vel non affixa ad planum rotæ; pondera idem valebunt* "*ac ſi ſuſpenderentur a punctis K et L, vel D et L.*" Now whether the Points of the Threads K, L, D, are fixed or not to the Plane of the Wheel is certainly of Importance, as it muſt make a Difference in the Points of Suſpenſion of the Weights, and conſequently in the Degrees of Obliquity with which the Weights act; for the loweſt Point of the Thread that is fixed to the Plane muſt be conſidered as the Point from which the Weight hangs; as the Parts of the Thread above that Point are quite uſeleſs not being at all acted upon. And from thence I ſhall endeavor to ſhew that to ſuppoſe the Weight A will have the ſame Power to turn the Wheel from whatever Point in the Line M A it hangs, is in Effect preſuppoſing what is intended to be proved. For it appears, from what he ſays immediately after, that, when the Weight

A hangs from the Point D, if its whole Force be expreſſed by the Line A D, and be reſolved into two Forces, D C and A C, the former only will have any Effect in turning the Wheel, as it acts perpendicularly on the *Radius* O D, while the latter is loſt, its Direction being parallel to O D. But it is evident, that, when the ſame Weight hangs from the Point K, as it acts perpendicularly on the *Radius* O K, its whole Force is exerted to turn the Wheel, and none of it loſt by oblique Action. Therefore the Force which the Weight A, exerts to oppoſe the Weight P, and turn the Wheel when it hangs from D, is, to the Force it exerts when it hangs from K, as the Line D C to A D, or as O K, to O D, (ſim. Triang. A D C, D O K) that is the Forces exerted by the Weight A, hanging from the Points D and K, are inverſely as the *Radii* O D, and O K. And therefore to ſuppoſe, that theſe two Forces will have the ſame Effect in turning the Wheel and oppoſing the Weight P, is the ſame as ſuppoſing that two Forces will have equal Effects in moving the Arms of a Lever (on which they act perpendicularly) when they are inverſely as the Lengths of thoſe Arms.——But this is the very Concluſion Sir *Iſaac* draws from his Premiſes, for he ſays: "*Pondera igitur A & P, quæ ſunt reciproce ut Radii in directum poſiti O K, O L, idem pollebunt et ſic conſiſtent in æquilibrio, quæ eſt proprietas notiſſima Libræ, Vectis et Axis in Peritrochio.*" But further, this Property of the Lever, which is here expreſſed in general Terms, includes two

Caſes. For the Arms of the Lever may be either perpendicular or oblique to the Directions of the Weights. The firſt of theſe Caſes is the ſimpleſt, and ſhould be firſt demonſtrated: And I do not ſee how there can be any room for applying the Reſolution of Forces in demonſtrating this Caſe, in which no Part of either Weight is loſt by oblique Action. But when this Caſe is proved, we have from thence, by the Reſolution of Forces, an eaſy Way of ſhewing, in the ſecond Caſe, when the Arms of the Lever are oblique to the Directions of the Weights, that the Weights will counterbalance each other, when they are reciprocally as the perpendicular Diſtances of their Lines of Direction from the Center of Motion. From the laſt of theſe Caſes, we may deduce an obvious Reaſon why the Weight A ſhould have the ſame Power to turn the Wheel, from whatever Point it hangs in the Line M A; the Truth of which, I am perſuaded, cannot be proved independent of thoſe Caſes, and therefore think it ought not to be uſed as a *Poſtulatum* in demonſtrating the general Property of the Lever.

Mr. *Maclaurin*, in his *View of Newton's Philoſophy*, after giving us the Methods which *Archimedes* and *Newton* have uſed for proving the fundamental Property of the Lever, propoſes one of his own, which, he ſays, appears to be the moſt natural one for this Purpoſe. However as to his

Method I ſhall only obſerve, that, from equal Bodies ſuſtaining each other at equal Diſtances from the *Fulcrum*, he ſhews us how to infer that a Body of one Pound (for Inſtance) will ſuſtain another of two Pounds at half its Diſtance from the *Fulcrum*, and from thence that it will ſuſtain one of three Pounds at a third of its Diſtance from the *Fulcrum*: and thus he goes on deducing, by a kind of Induction, what the Proportion is in general between two Bodies that ſuſtain each other on the Arms of a Lever. But this Argument he obſerves cannot be applied when the Arms of the Lever are incommenſurable, and therefore it cannot conclude generally, and conſequently is imperfect.

Theſe are the Methods of demonſtrating the fundamental Property of the Lever, which are moſt worth taking Notice of; and, ſince they ſeem liable to Objections, and the other Methods I have met with are ſtill more exceptionable. I ſhall propoſe a new Proof of this Property of the Lever, which appears to me a very ſimple one, and depends on a *Poſtulatum* that, I believe, will be readily granted.

If a Force be uniformly diffuſed over a right Line, that is, if an equal Part of the Force acts upon every Point of the Line, and if the whole Force acts according to one and the ſame Plane;

this Force will be ſuſtained, and the Line kept in *Æquilibrio*, by a ſingle Force applied to the middle Point of the Line equal to the diffuſed Force, and acting in a contrary Direction.

In order to ſhorten the following Proof, I muſt premiſe by way of *Lemma*, that, if a right Line be divided into two Segments, the Diſtances between the Middle of the whole Line, and the middle Points of the Segments, will be inverſely as the Segments. This is ſelf-evident when the Segments are equal; and, when they are unequal, then, ſince half of the whole Line is equal to half of the greater and half of the leſſer Segment, it is plain that the Diſtance between the Middle of the whole Line and the Middle of one Segment muſt be equal to half of the other Segment, ſo that theſe Diſtances muſt be to each other inverſely as the Segments, all which appears evident from the Inſpection of Fig. 2.

Let now the Line G H, (Fig. 2) whoſe middle Point is D, be divided into the unequal Segments G L, and L H, whoſe middle Points are C and F, and let two Forces or Weights, A and B, which are to each other as the Segments G L and L H, be applied to their middle Points C and F, and let them act perpendicularly on the Line G H. Then (by the *Lemma)* the Weights A and B will be to each other inverſely as C D, and F D, (the Diſtances of the Points C and F, to which they are applied from the middle of the whole Line) if then a third Force or Weight E, equal to the Sum of the Forces A and B, be applied to the Point D, and acts on the Line in an oppoſite Direction; I ſay theſe three Forces will ſuſtain each other, and keep the Line in *Æquilibrio.* For let us ſuppoſe the Force E to be removed and inſtead of it another Force, equal alſo to the Sum of A and B, to be uniformly diffuſed over the whole Line G H, and to act directly againſt the Forces A and B, then the Part of this Force which acts on the Segment G L, will be equal to the Force A, and therefore will be ſuſtained by it *(Poſtulatum)*; and the other Part, which is diffuſed over the Segment L H, will be equal to and ſuſtained by the Force B, ſo that the Forces A and B will ſuſtain this diffuſed Force and keep the Line in *Æquilibrio.* Let now two other Forces act alſo on this Line in oppoſite Directions, one of them the Force E acting on the Point D, as it was firſt ſuppoſed to do, and the other an uniformly diffuſed Force equal to E (and conſequently equal to the other diffuſed Force), then theſe two additional Forces will alſo balance each other, and therefore the *Æquilibrium* will ſtill remain. So that the two Forces A and B, and a diffuſed Force acting on one Side of the Line ſuſtain the Force E and a diffuſed Force acting on the other Side: but it is manifeſt, that in this *Æquilibrium*, the two diffuſed Forces acting on oppoſite

Sides are perfectly equivalent, and therefore if they are taken away from both Sides, the *Æquilibrium* muſt ſtill remain. Hence it appears that the three Weights or Forces A, B and E, any two of which are (by the Conſtruction) to each other inverſely at their Diſtances from the third, will ſuſtain each other and keep the Line on which they act in *Equilibrio*; which is the firſt and moſt ſimple Caſe of the Property of the Lever; for here the Directions of the Weights are ſuppoſed to be perpendicular to the Line on which they act, and it is evident that, if one of the Points C, D or F be fixed or conſidered as a *Fulcrum*, the Weights acting on the other two Points will continue to ſupport each other. I ſhall not now take the trouble of proving the ſecond Caſe of the Property of the Lever; it is moſt eaſily deduced from the firſt; for when two Weights act on the arms of a Lever in oblique Directions, and are to each other inverſely as the perpendicular Diſtances of their Lines of Direction from the Center of Motion, then, by the reſolution of Forces, it is eaſily proved that the Parts of thoſe Forces which act perpendicularly on the Arms of the Lever, and which only are exerted to turn the Lever, are to each other inverſely as the lengths of thoſe Arms; and therefore by the firſt Caſe they muſt balance each other.

I ſhall now mention ſome well known Truths in Mechanicks, which, I think, cannot be proved otherwiſe than by deducing them from what hath been here demonſtrated.

COROLLARY I. It appears from hence, that the Powers with which any two Forces move or endeavour to move the Arms of a Lever, are as the Rectangles, under Lines proportional to the Forces, and the perpendicular Diſtances of their Lines of Direction from the *Fulcrum.*

COR. II. When therefore two Bodies acting on the Arms of a Lever ſuſtain each other, if one of them be removed farther from the *Fulcrum*, it will preponderate; but if it be brought nearer to the *Fulcrum*, the other Weight will prevail: becauſe the Product to which its Force is proportional will be encreaſed in the firſt Caſe, and diminiſhed in the ſecond.

COR. III. We learn from hence, to find out the Center of Gravity of any two Bodies joined by an inflexible right Line; and to prove that its Definition will agree to one Point only in the Line. For if a Point be taken in the Line ſo that the Diſtances of the Bodies from it may be inverſely as their Weights, that Point will be their Center of Gravity, becauſe, when it is ſuſtained, the Bodies will be in *Æquilibrio.* But if the Line be ſuſtained at any other Point, then is the *Fulcrum* removed farther from one Body and brought nearer to the other than it was when the Bodies balanced each other; and therefore, by the preceding Cor. that Body from which it is removed, or which is on the ſame Side with the Center of Gravity, will deſcend. Conſequently there is but one Point in the Line, which being ſuſtained, the Bodies will continue in *Æquilibrio*, and therefore but one Point only can be their Center of Gravity. Hence alſo it appears, that the Center of Gravity will always deſcend, when it is not directly above or below the Point by which the Body is ſuſtained.

I ſhall now endeavour to be as conciſe as poſſible in what I have to ſay of the other Mechanic Powers; having, I fear, been too tedious in my Account of the Lever, which however deſerves to be particularly conſidered, ſince to it may be reduced the Balance, the Axle and Wheel, and (according to ſome Writers) the Pulley.

The Balance I do not conſider as a diſtinct Machine, becauſe it is evidently no other than a Lever fitted to the particular Purpoſe of comparing Weights together, and does not ſerve for raiſing Weights, or overcoming Reſiſtances, as the other Machines do.

When a Weight is to be raiſed by means of an Axle and Wheel, it is faſtened to a Chord that goes round the Axle, and the Power, which is to raiſe it, is hung to a Chord that goes round the Wheel. If then the Power be to the Weight as the *Radius* of the Axle to the *Radius* of the Wheel, it will juſt ſupport that Weight; as will eaſily appear from what was proved of the Lever. For the Axle and Wheel may be conſidered as a Lever, whoſe *Fulcrum* is a Line paſſing through the Center of the Wheel and Middle of the Axle, and whoſe long and ſhort Arms are the *Radii* of the Wheel and Axle which are parallel to the Horizon, and from whoſe Extremities the Chords hang perpendicularly. And thus an Axle and Wheel may be looked upon as a kind of perpetual Lever, on whoſe Arms the Power and Weight always act perpendicularly, tho' the Lever turns round its *Fulcrum*. And in like Manner when Wheels and Axles move each other by Means of Teeth on their *Peripheries*, ſuch a Machine is really, a perpetual compound Lever: and, by conſidering it as ſuch, we may compute the proportion of any Power to the Weight it is able to ſuſtain by the help of ſuch an Engine. And ſince the *Radii* of two contiguous Wheels, whoſe Teeth are applied to each other, are as the number of Teeth in each, or inverſely as the number of Revolutions, which they make in the ſame Time; we may, in the computation, inſtead of the *Ratio* of theſe *Radii*, put the *Ratio* of the Number of Teeth on each Wheel; or the inverſe *Ratio* of the Number of Revolutions they make in the ſame Time.

Some Writers have thought the Nature and Effects of the Pulley might be beſt explained by conſidering a fixed Pulley as a Lever of the firſt, and a moveable Pulley as one of the ſecond kind. But tho' the Pulley may bear being conſidered in that light; yet, I think, the beſt and moſt natural Method of explaining its Effects (that is, of computing the Proportion of any Power to the Weight it can ſuſtain by means of any Syſtem of Pulleys) is, by conſidering that every moveable Pulley hangs by two Ropes equally ſtretched, which muſt bear equal Parts of the Weight; and therefore when one and the ſame Rope goes round ſeveral fixed and moveable Pullies, ſince all its Parts on each Side of the Pullies are equally ſtretched, the whole Weight muſt be divided equally amongſt all the Ropes by which the moveable Pullies hang. And conſequently if the Power which acts on one Rope be equal to the Weight divided by the Number of Ropes, or double the Number of moveable Pullies, that Power muſt ſuſtain the Weight.

Upon this Principle, the Proportion of the Power to the Weight it ſuſtains by Means of any

Syſtem of the Pullies, may be computed in a Manner ſo eaſy and natural as muſt be obvious to every common Capacity.

The Proportion which any Power bears to the reſiſting Force it is able to ſuſtain by means of a Wedge, has been laid down differently by different Authors, as they happened to conſider it in particular Caſes. Without examining their ſeveral Opinions, I ſhall endeavour to expreſs this Proportion in one general Propoſition which may extend to the ſeveral Caſes in which the Wedge is applied.

Let the *Æquicrural* Triangle A B C, (Fig. 3.) repreſent a Wedge, the Lines A B and C B will be the Sides of the Wedge, A C its Baſe or Back, and its Height will be the Line P B biſecting the Baſe A C and alſo the vertical Angle A B C. When any two reſiſting Forces act on the Sides of a Wedge in Directions which make equal Angles with the Sides (as they are always ſuppoſed to do) a Power acting perpendicularly at P on the Baſe of the Wedge will keep the reſiſting Forces in *Æquilibrio*, when it is to the Sum of theſe Forces, as the Sine of half the vertical Angle of the Wedge, to the Sine of the Angle which the Directions of the Forces contain with the Sides of the Wedge.

For let E and F be two Bodies acting on the Sides of the Wedge, and let them be firſt ſuppoſed to act in the Directions E P and F P perpendicular to the Sides; then ſince the Power P acts perpendicularly on the Baſe A C, if theſe three Forces keep the Wedge in *Æquilibrio* they will be to each other as the Sides of a Triangle to which their Directions are parallel, or (which is the ſame thing) as the Sides of the Triangle A B C to which their Directions are perpendicular. Therefore the Power P is to the Sum of the reſiſting Forces which it ſuſtains as A C the Baſe of the Wedge to the Sum of the Sides, or as P A, half the Baſe, to A B one of the Sides; but P A is to A B as the Sine of P B A, half the vertical Angle of the Wedge, to the *Radius* which is the Sine of a right Angle, and the Directions of the reſiſting Forces are ſuppoſed in this Caſe to contain a right Angle with the Sides of the Wedge.

Let now the reſiſting Bodies E and F be ſuppoſed to act on the Wedge in Directions parallel to the Lines D P and O P, which make oblique Angles with its Sides, draw E G and F K perpendicular to thoſe Lines. From what has been proved it appears that the Power P is to the Force with which it is able, by means of the Wedge, to protrude the reſiſting Bodies in the Directions P E and P F as the Sine of half the vertical Angle to the *Radius*, let this protruding Force be expreſſed by the Line P E, and let it be reſolved into two Forces expreſſed by the Lines P G and G E, the former of theſe only will act in oppoſition to the reſiſting Bodies, therefore the whole protruding Force of the Power is to the Force with which it acts againſt the reſiſting Bodies P E and P F in the Directions P D and P O as P E to P G or, (becauſe the Triangles E P G and D P E are ſimilar) as P D to P E, that is as the *Radius* to the Sine of the Angle P D E; compounding therefore the *Ratio* of the Sine of half the vertical Angle to the *Radius*, with the *Ratio* of the *Radius* to the Sine of the Angle P D E, the Power P, when the Wedge is kept in *Æquilibrio*, will be to the Force with which it protrudes the reſiſting Bodies in Directions oppoſite to thoſe in which they act, as the Sine of half the vertical Angle to the Sine of the Angle P D E or P O F, which the Directions of the reſiſting Forces contain with the Sides of the Wedge.

Hence, when the Directions in which reſiſting Bodies act on a Wedge are given, we may eaſily find two Lines that will expreſs the Proportion between the Reſiſtance and the Power which ſuſtains it by means of the Wedge. For from P the middle Point of the Wedge draw the Line P D meeting one of the Sides, and parallel to the Direction in which the reſiſting Force acts on that Side, then the Power will be to the Reſiſtance as P D to P B the Height of the Wedge. For P D and P B are to each other as the Sines of the oppoſite Angles, in the Triangle P B D, that is as the Sines of half the vertical Angle, and the Angle which the Direction of the reſiſting Force contains with the Side of the Wedge.

From what has been demonſtrated we may deduce the Proportion of the Power to the Reſiſtance it is able to ſuſtain in all the Caſes in which the Wedge is applied. Firſt, when in cleaving Timber the Wedge fills the Cleft, then the Reſiſtance of the Timber acts perpendicularly on the Sides of the Wedge, therefore in this Caſe, when the Power which drives the Wedge, is to the coheſive Force of the Timber, as half the Baſe, to one Side of the Wedge, the Power and Reſiſtance will be in *Æquilibrio.*

Secondly, when the Wedge does not exactly fill the Clift, which generally happens becauſe the Wood ſplits to ſome Diſtance before the Wedge. Let E L F repreſent a Cleft into which the Wedge A B C is partly driven; as the reſiſting Force of the Timber muſt act on the Wedge in Directions perpendicular to the Sides of the Cleft, draw the Line P D in a Direction perpendicular to E L the Side of the Cleft and meeting the Side of the Wedge in D; then the Power driving the Wedge and the Reſiſtance of the Timber, when they ballance, will be to each other as the Line P D to P B the Height of the Wedge.

Thirdly, when a Wedge is employed to ſeparate two Bodies that lie together on an horizontal Plane, for Inſtance two Blocks of Stone; as theſe Bodies muſt recede from each other in horizontal Directions, their Reſiſtance muſt act on the Wedge in Lines parallel to its Baſe CA; therefore the Power which drives the Wedge will ballance the Reſiſtance when they are to each other as P A half the Breadth of the Wedge to P B its Height; and then any additional Force ſufficient to overcome the Reſiſtance ariſing from the Friction of the Bodies on the horizontal Plane will ſeparate them from each other.

The inclined Plane is reckoned by ſome Writers among the mechanic Powers; and I think with Reaſon, as it may be uſed with Advantage in raiſing Weights.

Let the Line A B (Fig. 4.) repreſent the length of an inclined Plane, A D its Height, and the Line B D we may call its Baſe. Let the circular Body G E F be ſuppoſed to reſt on the inclined Plane, and to be kept from falling down it by a String C S tied to its Center C. Then the Force with

which

which this Body ſtretches the String will be to its whole Weight, as the Sine of A B D the Angle of Elevation, to the Sine of the Angle which the String contains with a Line perpendicular to A B the Length of the Plane. For let the *Radius* C E be drawn perpendcular to the Horizon, and C F perpendicular to A B, and from E draw E O parallel to the String and meeting C F in O. Then, as the Body continues at reſt and is urged by three Forces, to wit, by its Weight in the Direction C E, by the Reaction of the Plane in the Direction F C, and by the Reaction of the String in the Direction E O; the Reaction of the String, or the Force by which it is ſtretched, is to the Weight of the Body, as E O to C E: that is, as the Sine of (the Angle E C O, which is equal to) A B D the Angle of Elevation, to the Sine of the Angle E O C, equal to S C O, the Angle which the String contains with the Line C F perpendicular to A B, the Length of the Plane.

When therefore the Sting is parallel to the Length of the Plane, the Force with which it is ſtretched, or with which the Body tends down the inclined Plane, is to its whole Weight, as the Sine of the Angle of Elevation, to the *Radius*, or as the Height of the Plane to the Length. And in the ſame Manner it may be ſhewn, that when the String is parallel to B D, the Baſe of the Plane, the Force with which it is ſtretched is to the Weight of the Body, as A D to B D, that is, as the Height of the Plane to its Baſe. If we ſuppoſe the String, which ſupports the Body G E F, to be faſtened at S, and that a Force, by acting on the Line A D, the Height of the Plane, in a Direction parallel to the Baſe B D, drives the inclined Plane under the Body, and by that Means makes it riſe to a Direction parallel to A D. Then, from what was proved in the third Caſe of the Wedge, it will appear, that this Force muſt be to the Weight of the Body, as A D to B D, or rather in a Proportion ſomewhat greater: if it makes the Plane move on and the Body riſe,

From this laſt Obſervation we may clearly ſhew the Nature and Force of the Screw; a Machine of great Efficacy in raiſing Weights or in preſſing Bodies cloſely together. For if the Triangle A B D be turned round a Cylinder whoſe Periphery is equal to B D, then the Length of the inclined Plane B A will raiſe round the Cylinder in a ſpiral Manner; and form what is called the Thread of the Screw, and we may ſuppoſe it continued in the ſame Manner round the Cylinder from one End to the other; and A D the Height of the inclined Plane will be every where the Diſtance between two contiguous Threads of this Screw, which is called a Convex Screw. And a Concave Screw may be form-

ed

ed to fit this exactly, if an inclined Plane every way like the former be turned round the Inſide of a hollow Cylinder, whoſe Periphery is ſomewhat larger than that of the other. Let us now ſuppoſe the Concave Screw to be fixed, and the Convex one to be fitted into it, and a Weight to be laid on the Top of the Convex Screw: Then, if a Power be applied to the Periphery of this Convex Screw to turn it round, at every Revolution the Weight will be raiſed up thro' a Space equal to the Diſtance between the two contiguous Threads, that is to the Line A D the Height of the inclined Plane B A; therefore ſince this Power, applied to the Periphery, acts in a Direction parallel to B D, it muſt be to the Weight it raiſes as A D to B D, or as the Diſtance between two contiguous Threads, to the Periphery of the Convex Screw.

The Diſtance between two contiguous Threads is to be meaſured by a Line parallel to the Axle; if we now ſuppoſe that a Hand-ſpike or Handle is inſerted into the Bottom of the Convex Screw, and that the Power which turns the Screw is applied to the Extremity of this Handle, which is generally the Caſe; then as the Power is removed farther from the Axis of Motion, its Force will be ſo much encreaſed (*vide* what was ſaid of the Lever, Cor. 1.) and therefore ſo much may the Power itſelf be diminiſhed. So that the Power, which, acting on the End of a Handle, ſuſtains a Weight by Means of a Screw, will be to that Weight, as the Diſtance between two contiguous Threads of the Screw, to the Periphery deſcribed by the End of the Handle. In this Caſe we may conſider the Machine as compoſed of a Screw and a Lever, or as Sir *Iſaac Newton* expreſſeth it, *Cuneus a vecte impulſus.*

Of any two or more of theſe ſimple Machines combined together, all other Machines however complicated are compoſed. And their Powers and Manner of acting may therefore be explained from the Principles here laid down.

AN ESSAY ON THE ASCENT OF VAPOURS,

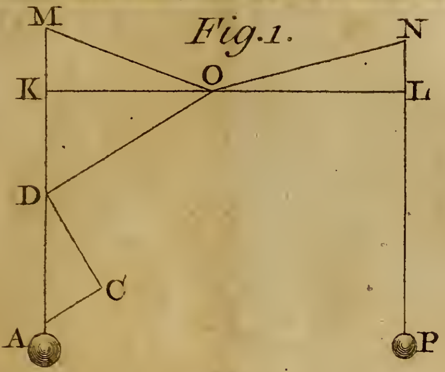
The Formation of

CLOUDS, RAIN and DEW,

And on ſeveral other

Phænomena of Air and Water.

Fig. 1.



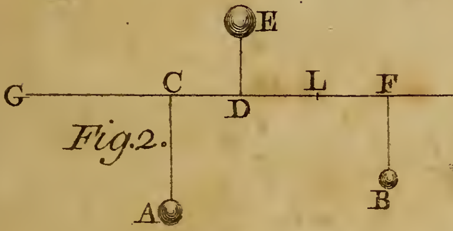


Fig. 2.

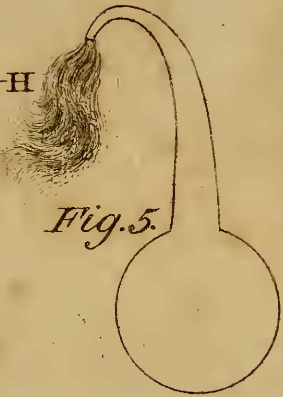


Fig. 5.

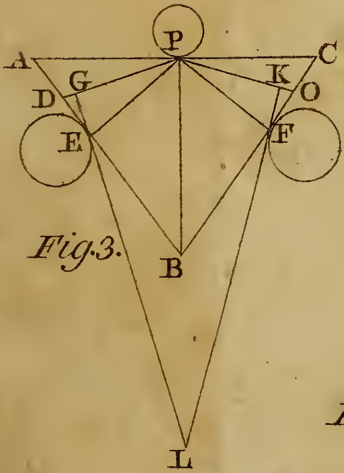


Fig. 3.

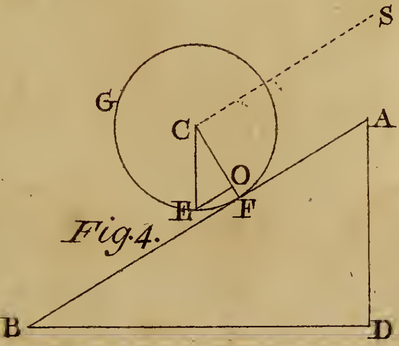


Fig. 4.

ON THE

ASCENT of VAPOURS, &c.*

I Intend in this Eſſay to give ſome account of the Nature of Evaporation, the Aſcent of Watery Vapours and ſeveral other Phanomena of the Atmoſphere. In explaining which I ſhall proceed upon a Principle very different (as far as I can find) from any that has hitherto been uſed on this

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* This Eſſay was read at a Meeting of the Royal Society on the 9th and 16th of *May*, 1765. communicated in a Letter to the Rev. *Charles Dodgſon*, D. D. F. R. S. now Lord Biſhop of *Oſſory*. *Vide Phil. Tranſ.* Vol. LIV. To which ſome Additions and Improvements have been ſince made by the Author.

Occaſion; whereby I ſhall avoid thoſe Objections which late Writers have made to the former Accounts that have been given us of theſe Phænomena, and perhaps deliver ſomething on this Subject that may appear ſatisfactory.

In all the Accounts I have met with, Fire, or Heat and Rarefaction, by which Watry Vapours are ſuppoſed to become ſpecifically lighter than Air, are made to be the principal, if not the only Cauſes of their Aſcent into the Atmoſphere. Doctor *Niewentyt*, and ſome others ſuppoſed, that the Particles of Fire, by adhering to thoſe of Water, make up *Moleculæ* or ſmall Bodies ſpecifically lighter than Air. And Doctor *Halley* thought, that by the Action of Heat the Particles of Water are formed into hollow Spherules filled with a finer Air, highly rarefied, ſo as to become ſpecifically lighter than the external Air. This laſt was the Opinion moſt commonly received, as Doctor *Deſaguliers* tells us in his Diſſertation on this Subject (publiſhed in *The Philoſophical Tranſactions*, in the Year 1729) in which he examines and refutes the two former Opinions, and endeavours to eſtabliſh his own. He aſcribes the Aſcent of Aqueous Vapours to their being turned into an Elaſtic Steam, and always rarefied more than the Air by the Degrees of Heat, to which Bodies are uſually ſubject in the different Seaſons of the Year.

This Opinion, I find, has been as ill received by ſubſequent Writers, as the former ones. Mr. *Clare*, in his *Treatiſe on the Motion of Fluids*, has brought many Objections againſt it; as Mr. *Rowning* has alſo done in his *Syſtem of Natural Philoſophy*, not long ſince publiſhed; who ſays, that the Cauſe of the Aſcent of Vapours has been much diſputed, but not yet determined by Philoſophers, and owns that he cannot think of any true Principle of Philophy upon which it may be accounted for.

I ſhall not here repeat the Objections made by thoſe Gentlemen, but muſt beg leave to add the two following, which, among many others that might ſtill be urged, they have not taken Notice of.

Firſt; If Heat was the only Cauſe of Evaporation, Water in a cloſe Room would evaporate faſter than when expoſed in a colder Place where there is a conſtant Current of Air, which is contrary to Experience.

Secondly; The Evaporation of Water is ſo far from depending on its being rarefied by Heat, that it is carried on even whilſt Water is condenſed by the Coldneſs of the Air. For Water is gradually condenſed by Cold, 'till the Moment it freezes; and ſince it evaporates even when frozen into hard Ice, it muſt evaporate in all the leſſer Degrees of Cold. Mr. *Boyle* having counterpoiſed a Piece of Ice in a Scale, hung it out in a froſty Night, and found next Morning that it loſt conſiderably of its Weight by Evaporation, "Who "would have thought, ſays he, that ſo extremely "hard and cold a Body would evaporate ſo faſt "in the clear Air of a freezing Night?" and ſince that Time others have obſerved the ſame Thing; which Fact ſeems to be an unanſwerable Objection to all the Accounts in which Rarefaction by Heat is made to be the chief, if not the only Cauſe of Evaporation: and therefore we muſt have Recourſe to ſome other Principle to aſſiſt us in accounting for this Phænomenon.

As the Author of Nature does not employ in his Works a greater Variety of Cauſes than is abſolutely neceſſary, it is the Buſineſs of natural Philoſophy to reduce as many Phænomena as may be to ſome general well-known Cauſe; and this is to be done by comparing the Phænomena together in their ſeveral Circumſtances, in which if they are found to agree, they are then to be conſidered as Effects of the ſame Kind, and aſcribed to the ſame Cauſe; by which Means, the Cauſes, whoſe Exiſtence is already proved, will be rendered more general, and our Knowledge more extenſive. Now, as the Suſpenſion of the Particles of Water in Air, of Salt in the Waters of the Ocean, and of other heavy Bodies in the Fluids that diſſolve them, ſeem to be Phænomena of the ſame Kind, we might reaſonably ſuppoſe, that they ariſe from the ſame Cauſe, and that what we call Evaporation is nothing more than a gradual Solution of Water in Air. But that I may not propoſe this merely as an *Hypotheſis*, I ſhall endeavour to prove the Truth of it, by conſidering the Nature of Solution in general and comparing its Properties and Effects with thoſe of Evaporation.

By Solution we underſtand, ſuch an intimate Union between the Particles of a Body and thoſe of a Fluid, that the Whole ſhall appear an Homogeneous Maſs, as tranſparent as the Fluid was before ſuch Union, and ſhall ſo continue, 'till ſome external Cauſe produces a Change. The Nature of Solution has been explained by the Writers on Chymiſtry in this Manner; When the Particles of any Body ſurrounded by a Fluid are leſs ſtrongly attracted by each other than by the Fluid, they muſt ſeparate from each other, and join themſelves to thoſe of the Fluid, and remain ſuſpended therein: Thus various Salts are diſſolved in Water, eſſential Oils in Spirits of Wine, Gold in *Aqua Regia*, Mercury, Silver and other Metals in other acid Spirits; and indeed it ſeems to be with great Appearance of Reaſon, that the Attraction between the minute Particles of different Bodies (of which we have ſo many other Inſtances) is aſſigned as the Cauſe of that Union between them, which we experience in Solutions; the chief Properties of which I ſhall now mention, ſo far as may be neceſſary for the Purpoſe to which I mean to apply them.

In moſt Caſes a diſſolving Fluid, or *Menſtruum* as the Chymiſts call it, will diſſolve or take up only a certain Proportion of the Body immerſed, and if then any more of the ſame Body be added, it will [redacted] fall to the Bottom, and then the Fluid is ſaid to be *ſaturated* with the Body it has diſſolved; yet a Fluid which is ſaturated with one Body may afterwards diſſolve others of different Kinds, and keep all their Particles ſuſpended together.

When any *Menſtruum* has entirely diſſolved a Body, it will continue as tranſparent as it was before; the Cauſe of which may be aſſigned from what Sir *Iſaac Newton* diſcovered by Experiments, *viz.* that the Particles of Bodies muſt be of a certain Size or Bigneſs to cauſe any Reflection or Refraction of the Rays of Light at their Surfaces to which Opacity is owing; whence he gives the Reaſon, why ſome Bodies are opake and others tranſparent. He alſo obſerves, that the moſt opake Bodies (ſuch as Metals) being diſſolved in an acid *Menſtruum*, and thereby reduced to their ultimate and ſmalleſt Particles, do not take away the Tranſparency of the *Menſtruum*.

Hence we may always know how to diſtinguiſh a Solution from a Mixture. For, if a Body be reduced to Powder and thrown into a Fluid that will diſſolve it, and they are then ſhaken ſuddenly together, the Fluid will continue ſomewhat opake, 'till the Solution be effected, or 'till what remains undiſſolved falls to the Bottom; for in this Caſe, the Particles are not at firſt reduced to their ſmalleſt Size, as they always are in a Solution. I think therefore we may conſider the Tranſparency of an heterogeneous Fluid (or one that contains in it Particles of another Body) as the *Criterion* of a true Solution; and where that is wanting, it is only a Mixture; as when Water and Air appear together in Froth, or in a Cloud, or a thick Miſt, it is only a Mixture of thoſe Bodies, and not a Solution of one in the other.

This much being premiſed concerning the Nature of Solutions in general, I proceed to the Proof of what I propoſed; and in Order to this, I ſhall ſhew that there is a mutual Attraction between Water and Air, the ſame that we obſerve between the Particles of any two Bodies, one of which diſſolves the other. I ſhall then compare in ſeveral Inſtances, the Properties and Effects of common Solutions with thoſe of Evaporation; that from the exact Reſemblance between theſe two Phænomena, it may appear that they are natural Operations or Effects of a like Kind, and therefore to be explained upon the ſame Principle, or aſcribed to the ſame Cauſe. Thence I ſhall ſhew, how the Aſcent of Vapours, and ſeveral other Phænomena of the Atmoſphere may be accounted for. And laſtly, I ſhall add ſomething on the riſing of Steam from boiling Liquors, and ſhew wherein it differs from common Evaporation.

I am firſt to prove that there is an Attraction between the Particles of Air and Water. It is well known, that all Water contains a conſiderable Quantity of Air, that retains its Elaſticity by Means of which it may be ſeparated from the Water by boiling and including it in an exhauſted Receiver. And it has been proved by Experiments, that Air extricated from Water by boiling, and reſtored to its uſual Denſity, will occupy a Space greater than that poſſeſſed by the Water in which it was contained. Now ſince it is allowed that the Particles of ſo heavy a Body as Gold are ſuſpended in *Aqua Regia* by their Attraction towards the Particles of that Fluid, it ſeems reaſonable to ſuppoſe, that ſo light and elaſtic a Body as Air muſt be retained under Water by a like Force, without which it would always aſcend to the Surface and eſcape. But that there is really ſuch an attractive

Force between Air and Water, has been fully proved by the following Experiment.

Let an Oil-Flaſk be filled almoſt full with Water, deprived of its Air, as much as may be; let the Mouth of it be then ſtopped, until the Neck being inverted is immerſed in a Veſſel of Water; a Bubble of Air will then aſcend into the upper Part of the Flaſk. When Things have ſtood in this Way for ſome Days, the Water will be found to have abſorbed the whole Bubble of Air (if it was not too large) and entirely filled the Flaſk. But if the Bubble was too large, part of it will be left; for the Water, after ſome time, will abſorb no more Air, being then ſufficiently ſaturated with it. It is obſervable that a Part of the included Air enters pretty quickly into the Water at firſt, but what remains afterwards makes its Way in but very ſlowly. This Experiment ſhews that Water, when deprived of its Air, will again draw the Air gradually into its Pores; juſt in the ſame Manner as a Lump of dry Sugar will draw up Water into its Pores, which will aſcend pretty quickly at firſt, but very ſlowly after ſome Time. We have Reaſon therefore to conclude, that there is the ſame kind of Attraction between Air and Water, that there is between Water and any dry porous Body that will imbibe it.

As Water contains a conſiderable Quantity of Air, ſo does Air contain a good deal of Water, even when we think it quite pure and dry; as appears from the Moiſture drawn from it by dry Salt of Tartar, in ſuch Quantity as to make the Salt become entirely fluid. Now ſince the Air is an heterogeneous Fluid containing in it Particles of another Body, and yet retaining a perfect Tranſparency, which is the *Criterion* of a true Solution in other Caſes; why ſhould we not infer from Analogy, that in this Caſe alſo there is a true Solution of Water in Air?

But the Truth of this will be confirmed by farther comparing the Properties of common Solutions with thoſe of Evaporation; which I ſhall now do in ſeveral Inſtances.

Firſt; When a Body is immerſed in a Fluid that diſſolves it, for Inſtance a Lump of Salt in Water, we ſee the Salt ſoon begin to diſſolve, and impregnate with its Particles the Water that ſurrounds it, which will then appear thick and loaded, and if the Water be at Reſt the Solution will proceed very ſlowly; but if it be ſtirred about, the Salt will ſoon be entirely diſſolved. How exactly does this correſpond with what Dr. *Halley* remarked in an Experiment he made on the

Evaporation of Water in a cloſe Room? (*Philoſ. Tranſ.* No. 192.) "The ſame Obſervations "ſays he, do likewiſe ſhew an odd Quality in "the Vapours of Water, which is, that of adhering "to the Surface that exhales them, which they "clothe as it were with a Fleece of vapourous "Air, which once inveſting it, the Vapour riſes "afterwards in much leſs Quantity." Here we ſee, that the Air which lay at reſt over the Water appeared thick and loaded with the aqueous Particles, and then the Evaporation proceeded very ſlowly; juſt as the Water that lies about the Salt, appears thick and loaded, and while it continues at reſt, the Salt is diſſolved but ſlowly. He alſo obſerves on the ſame Occaſion, that Evaporation is vaſtly promoted by a Current of freſh Air paſſing over the exhaling Surface: and this I have no doubt happens for the ſame Reaſon that Solution is greatly promoted by Agitation, which continually brings freſh Particles of the Fluid into contact with the Body it diſſolves, in the Place of thoſe that have been already ſaturated. [A]

Secondly,

[A] This Fleece of vapourous Air that ſometimes hangs over Water, is very diſcernable when we ſtand by the Sea-ſide in a hot calm Day, and is the Cauſe of ſome odd Appearances. For the lower Part of the Air, which is then much impregnated with Water, refracts the Rays of the Light more ſtrongly than at other Times, and by this unuſual Degree of Refraction, Houſes

Secondly; Into a Glaſs of clear cold Water throw a Lump of any Salt which is ſoluble in it, and when it has ſtood a little Time, ſhake the Glaſs or ſtir the Water very gently, and the Water which is ſaturated with the Salt will riſe up among the reſt of the Water in curled Wreaths or long *Striæ*, which will render the Water ſomewhat opake, cauſing it to refract in different Directions the Light of an Object ſeen through it, and will make the Object appear to have a tremulous Motion; this will continue until all Parts of the Water are equally impregnated with the Salt, and then its Tranſparency will be reſtored. As the Parts of the Water which are impregnated with the Salt are of different Denſities from the reſt, while they are mixing together, they muſt occaſion thoſe Refractions and this apparent tremulous Motion, which will ceaſe as ſoon as all the Water becomes of the ſame Denſity. The very ſame Appearances will attend the mixing together of any two Fluids of different Denſities, and which will thoroughly incorporate with each other.

Houſes on the Shore at a Diſtance from us appear almoſt as high as Steeples, remote Ships and Iſlands and the extreme Parts of Head-lands or Promontories appear to be raiſed quite out of the Water, and to hang in the Air above its Surface.

In like manner, when Smoke or Steam, iſſuing from the Pipe of a boiling Veſſel, firſt riſes into the Air, it appears in curled Wreaths and renders the Air opake; but as ſoon as it is entirely diſperſed, the Tranſparency is reſtored. Thus alſo in a calm, hot, Sun-ſhine Day, when we look along a moiſt Piece of Ground, the Air and any Object ſeen through it appear to have a tremulous Motion, like that which we obſerve in an Object, ſeen through two Fluids which are mixing together. Now, as the Vapours riſe here in great Abundance and the Air has but little Motion, thoſe Parts of it that are much impregnated with aqueous Particles are mixed gradually with the Air that is drier and of a different Denſity; which will occaſion Refractions of the Light, and that apparent tremulous Motion, juſt now mentioned; and in this Caſe, the Solution of Water in Air (if I may yet venture to call it by that Name) is carried on in a Manner viſible to the Eye, as Solutions are in other Fluids. The ſame tremulous undulating Motion is more obſervable, when we look in warm Weather through a Teleſcope, which magnifies the Vapours floating in the Air: and from this kind of Refraction the twinkling of the Stars ſeems to ariſe; with this Difference only, that the watry refracting Particles in the Day-time are paſſing into a State of Solution, whereas the Vapours already diſſolved are by the Cold of the

Night beginning to precipitate, and return into Particles large enough to cauſe Refractions in the Light of the Stars.

Thirdly; Heat promotes, and Cold in ſome Meaſure ſtops or checks both Solution and Evaporation. Very hot Water will diſſolve Salt ſooner and in a greater Quantity than cold Water; and if a ſtrong Solution of Salt be made in hot Water, the Water when cold will let go ſome of the Salt before diſſolved, which will fall to the Bottom in ſmall Particles or ſhoot into Chryſtals. Juſt ſo will Water evaporate faſter in warm than in cold Air; and the aqueous Vapours ſuſpended in the Air during the Heat of the Day, fall down at Night and form themſelves into Drops of DEW, or if the Night be very cold appear next Morning Chryſtalized in a HOAR-FROST. And thus if in a hot Day a Bottle be filled with any very cold Liquor, and expoſed to the warm Air, which to us ſeems very dry, a Dew will be ſoon formed on the outſide of the Bottle; for the Air about it becoming cold will let go Part of its Moiſture, which will be attracted to the Surface of the Glaſs; for the ſame Reaſon a Dew is formed on the Inſide of the Windows of a warm Room which on their Outſide are expoſed to the cold Air. Hence alſo we may obſerve, that as there cannot be ſo continual and copious an Evaporation in cold Weather, the Air will then be generally clearer than it is in hot Weather.

Heat ſeems to promote Solution, becauſe it expands Bodies, and thereby enlarges their Pores, and leſſens the coheſive Attraction of their Particles; ſo that a Body, when hot, will more eaſily admit a diſſolving Fluid into its Pores, and its Particles not cohering together ſo ſtrongly, as when cold, will more readily quit each other, and unite themſelves to the Particles of the Fluid by which they are attracted; and for the ſame Reaſon Heat will alſo promote the Evaporation of Fluids.

But fourthly; The Quantity of a Body diſſolved, and of a Fluid evaporated, in a given Time, depends (*cæteris paribus*) on its Quantity of Surface. Thus a Body reduced to Powder is ſooner diſſolved than when it is in a ſolid Form; and thus Smoak or Steam (which is Water reduced to very ſmall Particles by Heat) is much ſooner diſperſed and incorporated with Air, than Water in its uſual Form.

Fifthly; Chymiſts obſerve, that when Sea-Salt, *Sal Ammoniac*, or Nitre, is diſſolved in Water, or eſſential Oils in Spirit of Wine, ſome Degree of Cold is produced in the immediate Act of Solution; and the quicker the Solution, the greater is the Cold. By diſſolving pounded Ice, or rather Snow (whoſe Particles have a greater Surface) in Spirit of Nitre, a Degree of Cold has been produced ſo great as to freeze Quick-ſilver. Cold is likewiſe produced in the Act of Evaporation. For if Spirit of Wine, or Æther, having the ſame Temperature with the Air, be rubbed lightly with a Feather over the Ball of a Thermometer, it will ſink as the Spirit evaporate; and the quicker they evaporate, the faſter will the Thermometer ſink; thus I have made Water freeze in a thin Glaſs merely by the Evaporation of Æther promoted by a Current of Air. Water will likewiſe produce Cold, if it be uſed inſtead of Spirits, provided its Evaporation be promoted by a ſtrong Current of Air. That Cold is produced by the Evaporation of Water appears from the Practice of Sailors, who, in hot Climates, cool their Liquors by wrapping the Veſſels in wet Cloths, and hanging them up where they are much expoſed to the Wind and Sun, and wetting the Cloths again when they become dry.

This Obſervation ſhews a very remarkable Agreement between the Natures of Solution and Evaporation: How the Cold is produced in either Caſe, I cannot pretend to ſay; but I muſt beg leave juſt to apply this Fact, to account for a Thing which I believe moſt People have taken Notice of. If we rub Hungary-Water, or any other volatile Spirit over our Hand, it will feel much colder than Water, tho' they be both of the ſame Temperature, and will both feel equally cold, if we dip our Finger into each. The Reaſon of which is, that the Spirit evaporating much quicker than the Water, produces thereby a greater Degree of

Cold. And ſo Æther, if it be applied in the ſame Way, will feel colder than any other Spirit, on Account of its more ſudden Evaporation.

Sixthly; It is known, that rectified Spirit of Wine, when purged of Air, will imbibe a large Bubble of Air in a much ſhorter Time than Water will do, and I have myſelf experienced the Truth of this, which ſhews that there is a ſtronger Attraction, or *affinity* (as the Chymiſts call it) between Spirit of Wine and Air, than between Water and Air, and ſince the Spirit evaporates much faſter than the Water, I think we may conclude from hence, that the Evaporation of Fluids ariſes from an attractive Force between their Particles and thoſe of Air. [B] But here it muſt be obſerved that the Spirit is not only more ſtrongly attracted by the Air than Water is, but, being alſo more eaſily

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[B] As Water and Spirit of Wine are in no degree viſcid, they may evaporate in Proportion to the Attraction between them and Air. But the Caſe is very different in ſuch Fluids as are viſcid; for tho' I found that Oil of Olives, when purged of Air, will imbibe a Bubble of Air almoſt as ſoon as Water does, yet the Evaporation of Oil, is ſcarcely (if at all) ſenſible. The Reaſon of which muſt be, that the Attraction between Air and the Oil is not able to overcome the Tenacity of its Particles and ſeparate them from each other, tho' it is ſufficient to draw into the Oil the Particles of Air, which have no Attraction towards each other; juſt as Water is drawn into a Sponge, tho' the Attraction of the Water is not able to ſeparate the Particles of the Sponge from each other.

rarefied by Heat, its Particles ſeem to cohere together more ſlightly than thoſe of Water, and therefore may be more eaſily ſeparated by the Attraction of the Air.

Seventhly; If into any *Menſtruum* we throw a Body, which it diſſolves, and afterwards add another, to which the *Menſtruum* has a greater Affinity than it has to the firſt, it will diſſolve the ſecond Body, and let go the firſt, which will be precipitated and fall to the Bottom. In the very ſame Manner will a Fluid let go the Air it contains, upon the Addition of another Body to which it has a greater Affinity than it has to the Air. Thus if to well rectified Spirit of Wine we add an equal Quantity of clear Water, theſe Fluids (which ſo readily incorporate) having a greater Affinity to each other than to the Air they contain, will let go a great Part of that Air, which will riſe to the Top, or adhere in ſmall Bubbles to the Sides of the Veſſel. This, I think, ſhews that Air is contained in theſe Fluids, in the ſame Manner that the Particles of a Body are contained in a *Menſtruum* that diſſolves it; and hence I conclude that the Air which is imbibed by any Fluid is, properly ſpeaking, *diſſolved* in that Fluid; and conſequently that any Fluid which evaporates, or is imbibed by the Air, is alſo, properly ſpeaking, *diſſolved* in Air. Upon this Principle we may ſay, that Water is drawn out of the Air by dry Salt of Tartar, from its having a greater Affinity to that Salt than to the Air.

I ſhould not have been ſo tedious in comparing together the Natures of Solution and Evaporation in ſo many Inſtances, but that it gave me an Opportunity at the ſame Time of explaining ſome of the Phænomena that I at firſt intended to conſider; which Explanations I believe will be admitted, if I am right in the main Point I have endeavoured to prove. And really when we conſider how exactly Solution and Evaporation agree, in their ſeveral Appearances, Properties and Effects, I think we muſt be convinced that they are natural Operations of the ſame Kind, and that what we call Evaporation, is nothing more than a gradual Solution of Water in Air, produced and promoted by the ſame Means (to wit) Attraction, Heat, and Motion, by which other Solutions are effected.

I ſhall now endeavour to account for ſeveral Phænomena of the Atmoſphere upon this Principle, which will be ſtill further confirmed, if it be found to anſwer the Purpoſe to which it is applied.

The loweſt Part of the Air being preſſed by the Weight of the Atmoſphere againſt the Surface of the Water, and continually rubbing upon it by its Motion, has thereby an Opportunity of attracting and diſſolving thoſe Particles with which it is in contact and ſeparating them from the reſt of the Water. And ſince the Cauſe of Solution in this Caſe is the ſtronger Attraction of the Particles of Water towards the Air, than towards each other, thoſe that are already diſſolved and taken up, will be ſtill further raiſed by the Attraction of the dry Air which lies over them, and thus will diffuſe themſelves, riſing gradually higher and higher, and thereby leave the loweſt Air not ſo much ſaturated, but that it will be ſtill able to diſſolve and take up freſh Particles of Water. And thus Ice or Snow will evaporate as well as Water, its Particles being attracted and diſſolved by the Air, which is ſtrongly preſſed againſt its Surface; for tho' Heat promotes both Solution and Evaporation, yet we do not find that in either Caſe any ſenſible Degree of it abſolutely neceſſary. [c]

In this Manner will AQUEOUS VAPOURS aſcend ſlowly into the Atmoſphere, even when we ſuppoſe the Air almoſt at reſt, for I believe it is never perfectly ſo. But the Solution of Water in Air, and the Aſcent of Vapours, is greatly promoted by the Motion of the Winds, which bring freſh and drier Air into the Place of that, which may be already ſaturated and loaded with Moiſture, carrying it, together with its Moiſture, into the higher Parts of the Atmoſphere and diſperſing it into all Quarters.

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[c] Water by freezing is deprived of its Air, which we ſee gathered into Bubbles through the Ice, therefore the Subſtance of the Ice being deprived of Air, will attract the external Air more ſtrongly than common Water does, which is ſaturated with Air. And on this Account, I ſhould think it probable, that Ice, notwithſtanding its Hardneſs, will evaporate almoſt as faſt as common Water.

If we ſhould now ſuppoſe the Atmoſphere to remain always of the ſame Temperature as to Heat and Cold, and to have always the ſame Denſity; when it was once ſaturated with Water, all Evaporation would ceaſe, and the Vapours already raiſed would always remain ſuſpended; for a Fluid, while it remains of the ſame Temperature and Denſity, will never let go the Particles of a Body that it has diſſolved. We muſt therefore conſider what are the Cauſes which occaſion the Air ſometimes to part with the Water it has diſſolved, and which thereby keep up a continual Circulation of Vapours; and theſe I ſhall ſhew to be the frequent Viciſſitudes of Heat and Cold, Condenſation and Rarefaction, to which the Atmoſphere is ſubject.

As to the Effects of Heat and Cold, I have already ſhewn that the former promotes, and the latter checks or in ſome Meaſure hinders Evaporation as well as other Solutions; of which I gave an Inſtance in the Vapours that are ſuſpended in the Heat of the Day, and by the Cold of the Night are precipitated and ſuffered to coaleſce into Drops of Dew. From the Snow that lies ſo long on the Tops of the Mountains, and from the Experience of thoſe who have paſſed over them, we find that the higher Parts of the Atmoſphere are much colder than the lower. Now tho' Vapours are firſt raiſed, and abound moſt in the lower Parts of the Atmoſphere, yet they cannot there form themſelves into Clouds, becauſe the Heat that helped to diſſolve them, helps alſo to keep them diſſolved. But when they are carried by the Winds into the higher Parts, where the ſame Heat is wanting, the cold Air will not be able to keep diſſolved all that are carried up, but muſt ſuffer ſome of them to coaleſce into ſmall Particles, which ſlightly attracting each other and being intermixed with Air will form CLOUDS, having the very ſame Appearance with Steam or Smoke, which alſo conſiſts of ſmall Particles of Water *mixed* with Air and not yet *diſſolved* in it. Theſe Clouds when firſt formed will remain ſuſpended, though they conſiſt of Water, as well as

Air; becauſe the Weight of their Particles will not be able to overcome the Reſiſtance they muſt meet with in deſcending through the Air. For when Bodies are diminiſhed, their Quantities of Matter, to which their Weights are proportional, decreaſe faſter, or in a greater *Ratio*, than their Surfaces to which the Reſiſtance they meet with is proportional, and therefore in very ſmall Particles, this reſiſtance may become greater than their Weight. The different Heights at which Clouds are formed, depends on the Quantity of Vapours carried up, and the Degrees of Heat in the upper Parts of the Atmoſphere; for the Vapours may always aſcend 'till they meet with Air ſo cold or ſo thin that it is not able to keep diſſolved all that are carried up; hence Clouds are generally higher in Summer than in Winter. When Clouds are much increaſed by a continual Addition of Vapours, and their Particles are driven cloſe together by the Force of the Winds, they will run into Drops heavy enough to fall down in RAIN. Sometimes the Clouds are frozen before their Particles are gathered into Drops, and then ſmall Pieces of them, being condenſed and made heavier by the Cold, fall down in thin Flakes of SNOW, which appear to be Fragments of a frozen Cloud; but if the Particles be formed into Drops, before they are frozen, they become HAIL-STONES.

When the Air is replete with Vapours, and a cold Breeze ſprings up, which it often does from the Sea, the Solution of theſe Vapours is checked, and Clouds are formed in the lower Parts of the Atmoſphere, and compoſe what we call a MIST or FOG. This generally happens in a cold Morning, but when the Sun has been up for ſome time, the warm Air again diſſolves thoſe watery Particles, and it frequently clears up. In a hot Summer's Day the Air lying over wet Marſhy Ground is copiouſly filled with aqueous Vapours, but the Air growing cooler after Sun-ſet, will not be able to keep all thoſe Vapours diſſolved, but muſt let ſome Part of them unite quickly into very ſmall viſible Particles, and form thoſe Miſts which appear to riſe from Marſhy Grounds in a Summer's Evening. The Vapours near the Ground being more denſe and copious, will be firſt affected by the Cold, and afterwards thoſe that are thinner and higher up, ſo that the Miſt will be low at firſt, but will encreaſe in Height afterwards. But beſides, theſe Grounds and the Water they contain will acquire ſuch a Heat from the Sun that they may retain it for ſome time, and communicate it to the contiguous Air, ſo that the Vapours may continue to riſe for ſome time after Sun-ſet, and will become viſible when they get up a little Way into the cooler Air. After a warm and unclouded Day in

Summer there falls abundance of Dew, and the Air ſcarce recovers its clearneſs 'till towards Morning, when it is pretty much cooled; but on the firſt Return of Heat, at Sun-riſe or a little before it, the Water, which is then plentifully ſpread over the Ground and the Leaves of Trees and Plants in very ſmall Drops, begins again to diſſolve, and while it is diſſolving occaſions that HAZINESS ſo obſervable in a hot Summer's Morning about Sun-riſe and for ſome time after. Here it may be proper to obſerve, that when the Particles of Water are of a certain Size, they will render the Air equally opake, whether they are paſſing into a State of Solution, or returning from it.

Thoſe cold thick Morning Fogs I mentioned juſt now are often attended with a very light ſmall Rain; for the Vapours are then returning faſt from a State of Solution, and we ſee the Drops at their firſt Formation, and they are ſuch as we generally meet with in paſſing over high Mountains. So that it ſeems the Drops of Rain are very ſmall when firſt formed in the Clouds; but being driven about by the Motion of the Air in their Deſcent, ſome of them will probably touch each other and run into a Drop of a larger Size, and the farther they have to fall, the more will their Size be encreaſed before they come to the Ground. And for this Reaſon, the Drops which fall from the higher Clouds in Summer are found to be generally larger than they are in Winter, when the Clouds are low. It has been likewiſe obſerved that the Drops of Rain are remarkably large that fall in ſudden Thunder-Showers; of which the Reaſon may be, that the Lightning burſting from a Cloud and expanding itſelf greatly, will ſuddenly remove the Air from its Place, which Air muſt therefore return to its Place with great Violence, and thereby the watery Particles in the Clouds will be ſtrongly agitated and driven againſt each other, by which Means they will form themſelves into larger Drops than at other Times. Or perhaps it may be ſaid, that when a Cloud is filled with Lightning, which is the ſame as the electric Matter, the watery Particles like other electrified Bodies, will repel each other, but being ſuddenly deprived of this repelling Matter, will by their mutual Attraction come together again with ſome Velocity, and therefore will run into Drops larger than uſual.

When the Wind blows from the South, it is generally warm and comes replete with aqueous Vapours which it has diſſolved, but coming into a colder Climate it cannot there keep the ſame Quantity of Vapours diſſolved that it did before, and conſequently muſt part with ſome of them and let them precipitate; and therefore Southerly Winds generally bring us Rain. On the other

Hand, when the Wind blows from the North, or any Point near it, as it is very cold it cannot have diſſolved a great deal of aqueous Vapours where it came from, and therefore coming into a warmer Climate it is ready to diſſolve more. And on this Account theſe Winds, if they continue long, are found to be very dry and parching, and are generally attended with fair Weather.

Theſe ſeem to be the Effects of Heat and Cold, as far as the different Temperatures of the Air will occaſion it to diſſolve and take up, or let go and precipitate the aqueous Vapours, in conſequence of which we ſometimes perceive Changes of the Weather, even when there is no Change in the Height of the Barometer.

But Condenſation and Rarefaction will alſo have the like Effects in promoting the Solution of Water in Air, or in occaſioning ſome Part of what has been diſſolved to return again into Water and precipitate. It ſeems reaſonable to ſuppoſe, that denſe Air in which the Particles lie very near each other, will be better able to diſſolve and keep ſuſpended a Quantity of Water, than the ſame Air when diffuſed through a greater Space. And that this is really ſo, we have an experimental Proof. For when a Receiver is partly exhauſted, we ſee the rarefied Air begin to let go the Water

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it contained, whilſt gathering into ſmall Particles appears like Steam or Smoke falling to the Bottom. In order to prove the ſame thing by other Experiments, when a Cup of Water or rather of Spirit of Wine (which e[illegible] faſter) had ſtood for ſome time in a cloſe Receiver full of Air, I rarefied this Air ſuddenly by letting it ruſh into another Receiver that was exhauſted, and immediately the Vapour that was at firſt ſuſpended gathered into ſmall Particles and [illegible] in a very viſible Shower. I alſo took from the Air-pump a large exhauſted Receiver 20 Inches long, having at the Bottom a Braſs Plate, with a Stop-cock in the Middle of it, when the Stop-cock was opened, the external Air ruſhing in violently, and being much rarefied, let go the Water it contained, and threw it againſt the other End of the Receiver, where it ſtuck on the Glaſs, and covered it with a thin Dew, which I found to encreaſe until the Receiver was almoſt full of Air;

Theſe Experiments prove, that Air when rarefied, cannot keep as much Water diſſolved as it does in a more condenſed State. And hence we muſt conclude, that when the Atmoſphere is ſaturated with Water, and changes from a denſer to a rarer State, the higher and colder Parts of it eſpecially will begin to let go ſome of the Water before diſſolved; which will form new Clouds or add to the Size or Number of the Particles before formed, and thereby render them more apt to fall down in Rain. On the contrary, when the Atmoſphere changes from a rarer to a denſer State, it will then be able to ſtop the Precipitation of the Water and again diſſolve in the Whole, or in Part, ſome of thoſe Clouds that were formed before, and conſequently will render their Particles leſs apt to run into Drops and fall down in Rain. And thus we generally find by Experience, that the rarefied and condenſed States of the Atmoſphere are reſpectively attended with Rain or fair Weather. Though this does not happen at all times, for the Air, tho' rarefied, may not then abound much with aqueous Vapours, having already parted with a good deal of them. So likewiſe when the Air is denſe and heavy it may then be much loaded with aqueous Vapours, which will encreaſe its Weight, (and indeed it muſt be ſo after a long continuance of fair Weather) and we may then have Rain even before we can perceive by the Barometer, that the Atmoſphere changes to a rarer State. [D]

[D] The Vapours raiſed into the Atmoſphere will certainly add ſomewhat to its Weight, but the Difference in the Quantity of Water contained in the Air at one time and at another cannot make any conſiderable Change in its Weight. For the Quantity of Rain has been accurately meaſured that falls (*communibus annis*) in ſeveral Parts of Europe, and by taking theſe Quantities

Upon this Principle, I think we may account for the Changes of the Weather, which uſually attend the riſing and falling of the Mercury in the Barometer, better than by ſaying, that when the Air grows rarer and lighter, it cannot by the Laws of Hydroſtaticks ſo well ſupport the Clouds and Vapours, and therefore muſt permit them to fall down in Drops of Rain. For when the Air grows rarer, altho' the Clouds will deſcend into a lower and denſer Part of it, yet they will be there ſupported, and I do not ſee why their Particles ſhould be more apt to run into Drops there, than when they were higher up, unleſs they received ſome Addition from the Water depoſited among them by the rarefied Air, in the Manner I

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at a Medium, I find that in any one Place there will generally fall, one Year with another, as much Rain as would amount altogether to the Height of 28 Inches, which is equivalent in Weight to two Inches of Mercury; if therefore we were to ſuppoſe this whole Quantity of Rain to be ſuſpended in the Air at one Time, and then to fall before any more Vapours were taken up, the Mercury in the Barometer would, on that Account, fall two Inches. But we cannot make ſuch a Suppoſition, for the Rain falls in ſmall Quantities and at different Times, and the aqueous Vapours are again taken up into the Air immediately; ſo that the Difference in the Quantity of Water ſuſtained in the Air, at one Time more than at another, can add by its Weight but very little to the Height of the Mercury in the Barometer, probably not ſo much as the tenth Part of an Inch.

have juſt now mentioned. For ſince the Air is rarefied gradually, the Clouds can deſcend but very ſlowly, and therefore their Particles will not be ſo much preſſed together by the Reſiſtance they meet with in their Deſcent, as they generally are by the Winds which blow upon them.

When the Atmoſphere is ſaturated with Water, and grows colder and rarer than it was before, we ſhall then perceive the lower Air begin to part with ſome of the Water it contains, which will fall inſenſibly to the Ground, or adhere to the Walls of Houſes, or other Bodies expoſed to it, and make them become damp or wet. And if the Moiſture ſettles on the ſmooth Surfaces of cold Bodies, ſuch as Marble or other Stones, whoſe Pores cannot imbibe it, it will cover them with a kind of Dew, and then thoſe Bodies are vulgarly ſaid to SWEAT. At this time the Hygrometer being affected by the Moiſture will point to *WET*, and as we perceive from thence, that the Air is diſpoſed to part with the Water it contains, we may generally expect Rain. But when the Air again grows warm or denſe, it will be able again to diſſolve and take up the Water it before depoſited, and the Moiſture on the Bodies expoſed to it will diſappear, the Hygrometer will point to *DRY*, and we may then promiſe ourſelves fair Weather.

I obſerved before * that if a Bottle be filled with a very cold Liquor and expoſed to warm Air, a Dew will ſoon be formed on its Surface, by the Moiſture which the cooled Air depoſites. Now if we ſuppoſe this Body ſtill to retain the ſame Degree of Cold whilſt the Air paſſes over it, the Dew on its Surface will continually encreaſe and run down its Sides in ſmall Streams of Water. This ſeems to be exactly the Caſe of Mountains whoſe Tops reach into the colder Parts of the Atmoſphere, and which therefore are themſelves colder than the Air in general. For when the Wind blows the lower Parts of the Atmoſphere (which are the warmeſt and moſt replete with Vapours) againſt the Sides of the Mountains, it being there ſtopped in its Courſe, muſt neceſſarily aſcend and paſs over their Tops; this Air will therefore be conſiderably cooled in its Progreſs up the Sides and over the Tops of the Mountains, and conſequently muſt let go a great Part of the watery Vapours it contains; which will be precipitated in Dew and Moiſture, upon the Surface of the Mountains where it will ſink into the earthy Parts, or inſinuate itſelf into the Chinks and Crevices of Rocks, and being there collected will afterwards break out in SPRINGS and FOUNTAINS, and become the Source of RIVERS, which are known to take their Riſe in mountainous Countries. And on this Account

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count we might have ſmall Springs and Rivers near Mountains tho' there were neither Clouds nor Rain. But the Moiſture which the Air uſually depoſits on the Mountains muſt be conſiderably encreaſed by the Clouds which are driven againſt them, and accumulated by the Winds, for their Particles being then preſſed together will run into ſmall Drops of Rain. Beſides, it is well known that Mountains gather and retain the Clouds about them by their Attraction, in conſequence of which we often ſee ſome Clouds continue at reſt on the Mountains, whilſt the others are carried on gently by the Wind. Hence it is that Countries in the Neighbourhood of high Mountains are the moſt ſubject to frequent Rains.

Thus I have ſhewn how the Aſcent of aqueous Vapours and their conſtant Circulation, by precipitating again in Moiſture and Drops of Rain, will ariſe from the diſſolving Power of the Air, influenced by the Viciſſitudes of Heat and Cold, Condenſation and Rarefaction; which Cauſes, as they take Place in different Degrees, will occaſion thoſe various States of the Atmoſphere in reſpect to Dryneſs or Moiſture which we experience in the ſeveral Changes of the Weather. To which the Winds contribute very much by heating or cooling, condenſing or rarefying the different Parts of the Atmoſphere, and by promoting the Solution of Water in Air, as they mix thoſe

Fluids

Fluids together, or (when the Air is already ſaturated with aqueous Vapours,) by preſſing together the Particles in the Clouds, and thereby cauſing them to run into Drops.

If we may thus, from the known Properties of Solution, account in a ſatisfactory Manner for the Aſcent and Circulation of aqueous Vapours, and the ſeveral Phænomena of the Atmoſphere ariſing from thence; it muſt be a great Confirmation of the Arguments brought to prove that Evaporation is only a particular Species of Solution; and therefore that they both proceed from the ſame Cauſe, *viz.* the Attraction that obtains between the minute Particles of different Bodies, which is the Means of carrying on ſo many other Operations of Nature.

And indeed upon this principle, Air ſeems better fitted to be a general *Solvent* than any Fluid we know of; becauſe its Particles, not attracting each other, are more at liberty to unite themſelves to the minute Particles of ſuch Bodies as they do attract. And accordingly we find the Atmoſphere contains in it Matter of all kinds. The odoriferous Particles of Bodies ſeem to be ſtrongly attracted by the Air, as they are ſo very readily diſperſed thro' it; and Camphor, which is a very light Volatile Body, may be entirely diſſolved in Air without leaving any Remainder. The Air abounds with Vitriolic and other Acids, as is plain from the ruſting of Iron expoſed to it. It abounds alſo with ſulphurous, nitrous, and other inflammable Particles, as appears by the frequent Meteors kindled in it. For we have many Subſtances, ſuch as ſtrong Acids and eſſential Oils, which being thrown together will unite with ſuch Violence as ſuddenly to burſt into a Flame, and therefore when the Particles of thoſe Bodies, floating promiſcuouſly in the Air, happen to come together in a ſufficient Quantity by their mutual Attraction (which we know is very ſtrong) they muſt kindle into a Flame, and if many Particles of the inflammable Kind lie contiguous, the Fire will run in a Train and form, what we call, ſhooting Stars, and other blazing Meteors. In ſhort, the Atmoſphere may be conſidered as a Chaos containing Particles of all ſorts of Bodies; and as the great Inſtrument of Nature for keeping up a general Circulation of Matter; and by which not only Water is every where diſperſed, but oftentimes the Eggs of Inſects and the Seeds of Plants are conveyed from Place to Place, both which have been found in Rain-water, on examining it carefully juſt after it had fallen; and indeed we ſometimes find Inſects and Plants in ſome Places where their Appearance cannot well be accounted for, otherwiſe than by ſuppoſing their Eggs and Seeds to be conveyed thither by the Air.

I ſhall now mention two other Inſtances in which this diſſolving Power of the Air produces Effects of the utmoſt Importance. Dr. *Boerhaave*, ſpeaking of that Power or Quality of Air, which makes it neceſſary for the Preſervation of Animal Life; calls it a certain hidden Virtue, not to be accounted for from any of the Properties of Air then diſcovered. Perhaps we may be led to ſome Knowledge of it, by conſidering on what account Air may become unfit for Reſpiration by paſſing two or three times thro' the Lungs of an Animal, for we find that an Animal incloſed in ſuch Air will ſoon expire. I think we may be ſure that one Purpoſe, at leaſt, for which Air was deſigned is, the carrying off that Moiſture and other perſpirable Matter which conſtantly exhales from the Lungs, for this we know it actually does. Now as Air loſes nothing of its Elaſticity by paſſing thro' the Lungs, an Animal might ſtill continue to breathe the ſame Air, and it would ſtill continue fit for all ſuch Purpoſes in the Animal Oeconomy as may be anſwered by the alternate Expanſion and Contraction of the Lungs in Reſpiration. But this Air muſt in a ſhort Time become ſaturated with that Moiſture and other perſpirable Matter which it meets with in the Lungs, and muſt then loſe its Power of diſſolving and carrying off any more of that kind of Matter; which Nature intends ſhould be conſtantly diſcharged, and which will therefore continually encreaſe and thereby oppreſs the Lungs, heat the Blood, or produce ſuch other noxious Effects as are more immediately fatal than thoſe ariſing from the ſtoppage of external Perſpiration. So that an Animal incloſed in ſuch Air cannot live long, and will perhaps die ſomewhat in the ſame Manner as if it had been drowned. [E] Whether the Air we breathe may depoſite, in our Lungs, any kind of Matter neceſſary to the Support of Life, I cannot pretend to judge, nor is it my Deſign to enquire; what has been ſaid ſhews the neceſſity of freſh Air in Reſpiration, and by what Property it is adapted to anſwer one very important Purpoſe, and alſo how Air may ſoon become unfit for that Purpoſe. But here I will venture to aſk, whether it is not probable, that, in the conſtant and quick Evaporation of Moiſture from the Lungs, ſome Degree of Cold may be produced, as in other Evaporations, which

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[E] As Air even when incorporated with Water retains its Elaſticity, I took it for granted that it would not become leſs elaſtic by paſſing thro' the Lungs of an Animal. But finding that the contrary Opinion was held by ſome, who ſuppoſed that Air, having paſſed thro' the Lungs of an Animal, became unfit for Reſpiration by loſing its Elaſticity, I reſolved to try how the Fact was by the following Experiment. In a Receiver eight which, together with the freſh Air taken in, may ſerve to cool the Lungs and the Blood paſſing thro' them? We may ſee from hence that moiſt

eight Inches in Diameter and twelve Inches high, having under it a Piece of oiled Leather, I included a pretty large Chicken, and tied the Receiver cloſe down to the Table; thro' a Hole in the Top of the Receiver went a Glaſs Tube, open at both Ends, cemented round the Hole with Wax; the lower End was immerſed in Water (tinged blue) which ſtood in a Glaſs under the Receiver.

In about an Hour after the Chicken was included it grew much diſtreſſed, gaped wide and breathed with great difficulty, and in half an Hour more it ſeemed almoſt ready to expire; the Inſide of the Receiver was then covered with Moiſture which in ſome Places ran down in Drops.

Now if the included Air had loſt any of its Elaſticity by paſſing thro' the Lungs of this Animal, it could not have preſſed ſo ſtrongly on the Water in the Glaſs as it did at firſt, and then the external Air would have preſſed thro' the Tube, and appeared coming up through the Water in Bubbles. But no ſuch Thing happened, for as ſoon as the Receiver was tied down, the Water in the Tube roſe about one-fifth of an Inch above the Water in the Glaſs, and ſo continued during the whole Time of the Experiment, except that it roſe and fell near one-tenth of an Inch every time the Chicken breathed; and theſe Vibrations of the Water in the Tube I obſerved grew ſlower, and moved thro' a greater Space towards the latter End of the Time; which ſhewed that the Chicken then took in more Air every Time it breathed, than it did at firſt, endeavouring thereby to throw off the Moiſture which then oppreſſed its Lungs. After Things had ſtood thus above an Hour and a Half, thoſe who ſaw the Experiment were convinced that the included Air had not loſt any of its Elaſticity, tho' grown quite unfit for Reſpiration, the Animal being ready to expire in it.

Air muſt be very unwholeſome by its not ſufficiently promoting the neceſſary Perſpiration both internal and external.

Air is not leſs neceſſary for the Support of Fire than of animal Life; for Fire will not long continue to burn without a Circulation of Air. Now I ſuppoſe this happens, not from its adding any thing to the *Pabulum* of Fire, (for Fire ſeems to be otherwiſe ſufficiently provided with *Pabulum*) but rather on this Account; that the Air immediately about a Body on Fire is heated and made ſpecifically lighter than the Air at ſome Diſtance from it; This hot Air muſt therefore aſcend and carry with it all thoſe minute Particles of different kinds which are thrown off from the burning Body, and which would otherwiſe reſt upon its Surface, and thereby clog and ſtop the ſubtile Vibrations of the burning Matter, in which the Nature of Fire partly conſiſts. If therefore Fire be confined in a cloſe Place, where there can be no Circulation of freſh Air, the Air about it, being ſoon ſaturated with the Particles ariſing from the burning Matter, will not be able to take up any more of them, and therefore the Fire muſt go out, ſmothered as it were with ſuch Particles as are no longer combuſtible. And hence it is that Fire burns faſter when Air is ſtrongly blown upon it, for then the Aſhes are carried off as faſt as they are formed on the Surface of the burning Body, and thereby the Particles that have juſt taken Fire are kept quite free from any thing that can impede and clog their vibratory Motion. The Air in this Caſe will alſo ſpread the Fire quickly thro' the Fuel by blowing the Particles that are already kindled among thoſe that are not; and perhaps the Motion of the Air in this Caſe may promote the ſubtile Vibrations in the burning Matter by which the Fire is propagated thro' its Parts.

To this general Obſervation, that Air is neceſſary for the Support of Fire, we muſt admit one Exception; for Nitre will burn in a cloſe Veſſel or in *Vacuo*. The Cauſe of this ſingular Phænomenon I ſhall endeavour to aſſign from what has been ſaid. Nitre, when ſet on Fire, burns with more Rapidity and Violence than any Body we know of, it's burning is a kind of Exploſion and produces a very fierce and elaſtic Flame, for which Reaſon it is a neceſſary Ingredient in Gun-powder, *Pulvis fulminans*, and all other fulminating Compounds. When therefore a Piece of Nitre takes Fire, its elaſtic Flame drives off the Fumes and Vapours (with which the Air in the Veſſel may be then ſaturated) and defends the burning Matter, ſo that they cannot ſettle upon it and extinguiſh it, as they do other Bodies that burn ſlowly and without any Exploſion. And on this Account Nitre, and other inflammable Matter mixed with it, will burn in cloſe Veſſels or even in *Vacuo*. This will further appear from conſidering the Manner in which Nitre firſt takes Fire, and the Reaſon of its exploding Quality. Nitre will not burn by itſelf tho' melted and made red hot, but when it comes in Contact with any Body actually on Fire, and which therefore contains an inflammable Matter, or (as it is called) the *Phlogiſton*, it burſts into a Flame. Here the Chymiſts ſay, that the acid Spirit of the Nitre unites ſo rapidly with the *Phlogiſton*, which is detached from the burning Matter, that by the Violence of their Congreſs they both vaniſh together in a Flame. And they prove this to be ſo, by throwing ſtrong Acid of Nitre on any thick eſſential Oil, which conſiſts almoſt wholly of the *Phlogiſton*, for then the Mixture will ſuddenly burſt into a Flame with a violent Exploſion. Therefore ſo long as Nitre and the inflammable Matter are thus in Contact, no Fumes or Vapours floating about them can prevent that rapid Union between their Parts which muſt neceſſarily make them continue to burn. The Air, which is produced from burning Nitre may poſſibly add to the Elaſticity of its Flame. But I do not think it probable that this Air can contribute much to keep a large Quantity of Nitre burning ſo long as it will do in a cloſe Veſſel.

Having thus ſhewn by what Property Air produces the Evaporation of Fluids and ſeveral other Effects, I come now to treat of thoſe Vapours that are raiſed merely by Heat. Although

though the Particles of Fluids in common Evaporation are raiſed into the Atmoſphere by the attracting and diſſolving Power of the Air, yet in ſome particular Caſes Vapours will riſe into the Air on another Account. For in ſome Places the Earth often ſends forth hot elaſtic Vapours that riſe into the Air by Means of their Elaſticity, and carry up with them Mineral and Foſſile Particles of different kinds. Fermentation generates elaſtic Vapours which expand themſelves into the Air. And the Particles of Water and other Fluids, when ſufficiently heated, acquire a repelling Force which ſeparates them from the Surface, and throws them upwards into the Air. But all theſe Vapours ſoon loſe that Elaſticity by which they were at firſt raiſed, and they muſt then be retained and kept ſuſpended in the Air by the ſame Power that keeps up all the Vapours that riſe without any Elaſticity in common Evaporation.

That the Particles of Steam which riſe from hot Water are endued with a repelling Force appears plainly when Water is boiled in a cloſe Veſſel, for then the Steam becomes ſo exceedingly elaſtic that, unleſs proper Care be taken, it will burſt the ſtrongeſt Veſſel. In this Caſe the boiling Water, being ſtrongly preſſed by the Force of the included Steam, conceives a much greater Heat than it will ever do in an open Veſſel; for even when Water is boiled in the open Air it is ſomewhat

what hotter when the Atmoſphere is heavy, than when it is light, which ſhews that Preſſure upon boiling Water encreaſes its Heat; the Reaſon of which we may perhaps ſee preſently. But the moſt remarkable Phænomenon that attends the boiling of Water, is the large Bubbles which continue to riſe from the Bottom ſo long as the Water boils, and long after all the Air is driven out of it, of the Nature of which there have been various Opinions. Doctor *Boerhaave*, in his *Elements of Chymiſtry*, proves by ſeveral Arguments, that theſe Bubbles do not ariſe from Air, and with regard to their Production, he ſeems to be of the ſame Opinion with *Stairs* (to whoſe Work he refers) that they ariſe from ſome active Fires reſiding in the Water. *Marriotte*, whom he alſo mentions on this Occaſion, calls theſe Bubbles *Fulminations*, and ſuppoſes that they may proceed from ſome kind of ſaline Particles contained in the Water, which, being heated, act in the ſame Manner that the *Aurum fulminans* does when melted. It has been alſo a received Opinion that theſe Bubbles are occaſioned by ſome ſubtile elaſtic Fluid tranſmitted from the Fire through the Bottom of the Veſſel. However I conceive that a Fluid ſo ſubtile as to paſs thro' the Bottom of the Veſſel, would paſs alſo thro' the Water ſo eaſily as not to diſturb it; and therefore I have for ſome time ſuſpected, that theſe Bubbles are formed only by an elaſtic Steam in the Manner I ſhall now deſcribe. The Particles on the Surface of the Water, long before it boils, will, by Means of the repelling Force which the Heat introduces among them, riſe in Steam and will inſinuate themſelves into the Air which yields eaſily to them; but thoſe Particles that are preſſed againſt the Bottom, by the Weight of the Atmoſphere, and of the incumbent Water, will require a greater Degree of Heat to render them ſo elaſtic that they ſhall be able to overcome this Preſſure, and expand themſelves into a greater Space. Now ſince Heat expands Water and makes its Particles repel each other, according to its different Degrees, we muſt ſuppoſe that theſe Particles, from their being in contact with the Bottom of the Veſſel, will at length acquire ſuch a Degree of Heat as will give them a repelling Force ſufficient to overcome the Preſſure they ſuſtain, and to expand them ſuddenly into thoſe large Bubbles that aſcend thro' the Water when it boils violently.

I have lately made ſome Obſervations and Experiments which ſeem to confirm this Opinion. Theſe Bubbles which aſcend from the Bottom, I obſerved, always grow leſs in their Progreſs upwards, and thoſe ſmall Bubbles, that adhere to the Bottom for ſome time before they aſcend, often diſappear entirely before they reach the Surface, which ſhews that when the Matter they contain, or any Part of it, loſes the Heat it had at firſt, it is again turned into Water.

When Water that has juſt boiled, or is even conſiderably leſs hot than boiling Water, is poured into a Glaſs and ſet under the Receiver of an Air-Pump, and the Air is almoſt drawn out, the Water will boil more violently than it does on the Fire, the Bubbles breaking out from all Parts of it. In this Caſe, no ſubtile Fluid can be ſuppoſed to riſe thro' the Bottom of the Veſſel, but the Heat which the Water retains will then give its Particles an elaſtic Force ſufficient to overcome the Preſſure of what little Air remains in the Receiver, and will expand them into Bubbles. And that theſe Bubbles are compoſed of Steam appears plainly from this Experiment, for as ſoon as they begin to aſcend the Receiver is filled with Steam, which being condenſed by the Cold runs plentifully down its Sides in Water. From hence we may ſee the Reaſon why Water in *Vacuo* boils with a very ſmall Degree of Heat.

After a Veſſel of Water had boiled till all the Air-Bubbles were driven out of it, I turned upon its Mouth a large Glaſs that lay under the Water; the Bubbles, that aſcended under the Glaſs, remained in the upper Part of it, and forced out the Water it before contained, and then the elaſtic

Matter in the Glaſs overturned it, and aſcended to the Top in one large Bubble, upon which the Steam on the Surface was much encreaſed. Now this ſhews that the Matter contained in theſe Bubbles, which at firſt is quite tranſparent, being a very rare and homogeneous Fluid, appears afterwards like Steam when it is mixed with the Air. But I thought I ſhould make a concluſive Experiment if I could obſerve the Effects of a very hot Steam conveyed under boiling Water. Therefore when an * Æolipile had boiled till all the Air was driven out of the Water it contained, without taking it off the Fire, I immerſed its Pipe into a Veſſel of Water which had juſt been boiled, and immediately the Steam that iſſued from the Pipe roſe up in very large Bubbles thro' the Water, and made it appear to boil violently. I then held a large Glaſs of cold Water, ſo that the Pipe of the boiling Æolipile was immerſed in it; at firſt none of theſe Bubbles appeared, for the Steam, being then condenſed by the cold Water, was mixed thro' it, making a very loud and uncommon Noiſe: but as ſoon as the Water in the Glaſs grew very hot, this Noiſe ceaſed, and the Steam, being no longer condenſed, roſe in large Bubbles, as before, and made the Water appear to boil with great Violence.

Theſe

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* An *Æolipile* is a hollow Globe of Iron or Copper, into which is ſcrewed a long Pipe, whoſe End is commonly bent into a Curve; it has a very ſmall Orifice, out of which the Steam iſſues with great Violence, when Water is boiled in the *Æolipile*. See it delineated in Fig. 5.

Theſe Obſervations and Experiments ſeem to diſcover fully to us the Nature of thoſe Bubbles that aſcend thro' boiling Water; and lead me to make ſome further Remarks on the Degrees of Heat that different Liquors acquire in boiling.

The Parts of a Fluid neareſt the Bottom of a Veſſel grow hot firſt, and being then expanded and made lighter, they aſcend and change Place with the colder and heavier Parts, which occaſions that inteſtine Motion we perceive in Liquors while they are growing hot. And thus the Heat of the Whole will continue to increaſe, until thoſe Particles, that are in contact with the Bottom of the Veſſel, acquire ſuch a Degree of Heat as will give them a repelling Force ſufficient to overcome the Weight of the Atmoſphere, the Weight of the incumbent Fluid, and the Tenacity of its Particles, and then they will be ſuddenly expanded into Bubbles of Steam, and aſcend quickly to the Top, without communicating this Heat to the ſurrounding Fluid. For as theſe Bubbles have a Degree of Heat but little ſuperior to that of the Fluid, and juſt ſufficient to keep them expanded, if they were to loſe any of it, by communicating it to the Fluid in their Aſcent, they would all diſappear before they got to the Surface, as the very ſmall ones do which aſcend but ſlowly; or if the whole Fluid was to grow at once as hot as the Bubbles, it would, like them be all turned into an elaſtic Steam. And therefore the Fluid itſelf cannot grow hotter than it was when theſe Bubbles began to aſcend; but muſt all boil away in the ſame Degree of Heat. [F] Provided it be ſuch a Fluid as will not grow denſer, or more viſcid and tenacious by boiling, of this kind are Mercury, Water, Spirit of Wine, and ſeveral others, for theſe Fluids are found to boil reſpectively with 600, 212, and 175 Degrees of Heat, and afterwards they do not grow hotter. The Reaſon of which is plain, for whilſt the Preſſure upon a Fluid, and its Denſity and Tenacity continue the ſame, the ſame Degree of Heat will always be ſufficient to ſeparate its Particles and expand them into Steam; which is the greateſt Effect that Fire can produce on any Fluid without actually inflaming it. Hence it is obvious that an additional Preſſure on boiling Liquors, or an encreaſe of their Denſity or Tenacity, will, by keeping their Particles more ſtrongly together, enable

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[F] That theſe Bubbles are really hotter than the other Parts of the Fluid I found by immerſing a Mercurial Thermometer with *Fahrenheit's* Scale into a Veſſel of boiling Water, for it roſe one Degree higher when held among the Bubbles, where they were moſt numerous, than it did in the other Parts of the Water.

able them to bear a greater Degree of Heat before they are expanded into Steam and begin to boil. It is very obſervable that all oily Liquors, which refract the Rays of Light more ſtrongly than others do, acquire alſo a much greater Heat in boiling. Thus Oil of Turpentine and other thin eſſential Oils, that are procured by Diſtillation, boil with about 560 Degrees of Heat, which however as the boiling continues is always encreaſing; the more volatile Parts flying away, and leaving the Reſidue thicker, more viſcid, and ſuſceptible of greater Heat.

Common vegetable and animal Oils begin to boil with 600 Degrees of Heat, which is the ſame with that of boiling Mercury, and therefore the greateſt Heat that can be meaſured by a Mercurial Thermometer. But it has been found, by the Expanſion of an Iron Rod, that Oils grow continually hotter by boiling, and at length their Heat encreaſes ſo much that they burſt into Flame.

There is indeed one Obſervation, which, if true, would contradict what I have ſaid as to the Heat of boiling Liquors being in ſome Meaſure owing to their Viſcidity; for it is commonly ſaid that Tar, which is a viſcid Liquor, boils with ſo ſmall a Degree of Heat, that the Workmen ſkim the Droſs off it with their Hands. But this I found to be only the Appearance of boiling, for having placed a Veſſel of Tar on the Fire; as ſoon as the Thermometer ſhewed it to be a little hotter than the human Blood, a great Quantity of Air roſe out of it in Froth and Bubbles, carrying up ſome Droſs with it, and then I could eaſily bear to hold my Finger in it; but ſoon after when the Tar began really to boil the Thermometer roſe as high as it does in boiling Water, and was ſtill riſing. For Tar, when one half of it is boiled away, becomes Pitch; and it is well known that boiling Pitch is hotter than boiling Water; ſo that this Experiment correſponds exactly with the Theory I have laid down in regard to the Heat of boiling Liquors.

Hitherto we have conſidered only the Effects of ſuch Degrees of Heat as are great enough to expand Liquors into large Bubbles and make them boil, or to raiſe a viſible Steam from their Surface. But I find it neceſſary (for a Reaſon I ſhall mention preſently) to conſider alſo the Effects of the leſſer Degrees of Heat, down to that which is juſt ſufficient to keep Liquors in a ſtate of Fluidity.

It is generally allowed that Heat keeps Bodies fluid, by cauſing their Particles in ſome Meaſure to repel each other, and thereby preventing them from coming into ſuch cloſe Contact as would render them hard. Now I ſhall ſhew from Experiments that all Degrees of Heat above what is neceſſary to keep Liquors fluid, will raiſe from their Surface (provided they are not viſcid) ſome kind of Steam, which, for Diſtinction's ſake, I ſhall call an *Effluvium*. Under a large Glaſs ſet a Cup of Water, not hot enough to emit any viſible Steam, and let the Glaſs be expoſed to the cold Air, a Dew will ſoon appear on its Inſide. Here an Effluvium is raiſed from the Water, but it riſes too ſlowly and in too ſmall a Quantity to become viſible till it is condenſed on the Glaſs. As Steam riſes from hot Liquors more abundantly when the Preſſure of the Atmoſphere is taken away, it may be ſuppoſed that this Effluvium will alſo riſe more copiouſly from colder Liquors in the ſame Caſe, as we ſhall ſee it really does by what follows. From a great Number of Experiments made with Spirits of Wine, of different Degrees of Strength, I found that, at a Medium, the Quantities loſt in the ſame time in a cloſe Receiver full of Air, in one only half full of Air, in Air rarefied two and forty times, and in the open Air, were nearly in the Proportion of 1, $1\frac{5}{7}$, 6, and 48. The ſame kind of Spirit was uſed in each Experiment, the Time was 24 Hours, and the Spirits were contained in equal Cups, ſo that their Quantities and Surfaces were as nearly equal as might be. That all the Spirit uſed in each Experiment might be in the ſame Circumſtances, before I put it into the Cups I drew from it all the Air I could by the Air-pump, which could not rarefy the Air in the Receiver more than two and forty times, it was neceſſary to do this, becauſe the Spirit loſt five or ſix Grains in a few Minutes while the Air was drawing from it by the firſt Exhauſtion of the Receiver, and a Quantity leſs and leſs during the ſecond and third Exhauſtions. A Cup of Water when in a warm Room loſt one Grain on the firſt Exhauſtion, and when it had afterwards ſtood in the exhauſted Receiver for 24 Hours it loſt two Grains and a Half, while the ſame Quantity of Water loſt 35 Grains in the open Air; but Ice that was thawing, or Water with Ice in it, did not loſe any thing in the exhauſted Receiver, or in a cloſe Receiver full of Air. Theſe Experiments were made in a large Room without a Fire, and the Fluids were of the ſame Temperature, whoſe loſſes I compared together.

The Spirit of Wine, which is ſo eaſily rarefied by Heat, and which (as it never freezes) has always more Heat than is ſufficient to keep it fluid, loſt in every Experiment conſiderably more than Water did in the ſame Circumſtances; and as Water did not loſe any of its Weight, when it had not more Heat than was neceſſary to keep it fluid, I think the riſing of an Effluvium from theſe Liquors may juſtly be aſcribed to the repelling Force given to their Particles by certain Degrees of Heat. The

Air in the Receiver did not contribute to this Effect, but on the Contrary prevented it, in a great Meaſure, by its Preſſure, for the more Air was drawn from the Receiver, the greater Quantity of this Effluvium aroſe. I obſerved, that when the Air was rarefied two and forty times, the Effluvium that roſe from the Spirit, which was ſometimes near forty Grains in twenty-four Hours, not being ſupported by a ſufficient Quantity of Air, and loſing its firſt Elaſticity by being very much expanded, fell by its Weight to the Bottom, and covered it and the lower Parts of the Receiver with Moiſture. But none, or very little, of this Moiſture appeared when only one half of the Air was drawn out of the Receiver, for the Effluvium which then aſcended, (amounting generally to eight or nine Grains) was ſupported by the remaining Air; but when I rarefied this Air ſuddenly, as in an Experiment before mentioned, (Page 59.) the Effluvium was immediately gathered into a vaſt Number of viſible Drops, and fell to the Bottom. This plainly ſhews that the Effluvia which are raiſed from Liquors, by theſe very ſmall Degrees of Heat, cannot continue ſuſpended, unleſs they are ſupported by a ſufficient Quantity of Air.

I thought it neceſſary to make theſe Experiments and Obſervations, in order to obviate an Objection which might be made to the Principle I have endeavoured to eſtabliſh. For as it is found that Fluids loſe of their Weight both in an exhauſted Receiver, and in the open Air, it might be ſaid that this loſs proceeded from the ſame Cauſe in both Caſes, and therefore that common Evaporation did not depend on the diſſolving Power of the Air. But from theſe Experiments, I think, we might give a ſufficient Anſwer to ſuch an Objection. For it appears firſt; that Ice, or Water that has no more Heat than is neceſſary to keep it fluid, loſe nothing of their Weight in an exhauſted Receiver, tho' they loſe very conſiderably in the open Air. Secondly; The Quantity which the Spirit of Wine loſt by Evaporation in the open Air was eight times greater than what it loſt in the ſame time by an Effluvium, when the Air in the Receiver was rarefied two and forty times; therefore the Cauſe of Evaporation muſt be a much more powerful one than that which raiſed the Effluvium. And further, the Quantity loſt by Evaporation was forty-eight times greater than what was loſt, in the ſame time, by an Effluvium when the Receiver was full of Air; therefore, ſuppoſing the ſame Effluvium to riſe from it in the open Air, we muſt allow that of the whole Quantity which the Spirit of Wine loſt in the open Air, one Part only in forty-eight could be owing to that Effluvium which is occaſioned merely by its Heat, conſequently forty-ſeven Parts muſt have been carried off by ſome very powerful Action of the

Air; which muſt alſo be the ſole Cauſe of the Evaporation of Ice or very cold Water, which are found not to emit any Effluvia in an exhauſted Receiver. And this Action of the Air I have ſhewn to be its diſſolving Power.

Before we conclude, it may not be amiſs to take a general View of the important Purpoſes which Air is contrived to anſwer, and of the Means by which it is adapted to theſe ſeveral Purpoſes. By its Subtilty and Elaſticity it is capable of being eaſily taken into the Lungs of Animals; and by its attracting and diſſolving Power it carries on that Perſpiration, both internal and external, which we find is neceſſary to the Preſervation of Life. By the ſame Power it takes away the ſuperfluous Moiſture from Trees and Plants, and thereby promotes Vegetation. By the ſame Power it raiſes and ſuſtains aqueous Vapours, and its Temperature and Denſity being eaſily changed, it returns them again in Rain and Dew, and thus keeps up a continual Circulation of Moiſture. By the ſame Power it contributes to the Support of Fire, by carrying off from burning Bodies all ſuch Fumes and Vapours as would otherwiſe extinguiſh them.

By its Weight and Preſſure on the Surface of Fluids it keeps their Particles together and enables them to bear (without being diſperſed in Steam) ſuch Degrees of Heat as are neceſſary for all thoſe Uſes to which boiling Liquors are applied. By the ſame Preſſure it raiſes Water in Pumps and other Hydraulick Engines.

And laſtly; we may add to theſe, all the various Purpoſes to which the Winds are ſubſervient; and which are too many to be enumerated, and too well known to require being particularly mentioned.

Obſervations *and* Conjectures

On the Nature of the

AURORA BOREALIS

AND THE

TAILS of COMETS.

N

OBSERVATIONS

AND

CONJECTURES, &c.

HAVING obſerved that ſome late Writers, who endeavour to revive the exploded Hypotheſis of an univerſal *Plenum*, bring Arguments in favour of their Opinion from what Sir *Iſaac Newton* ſays of the Aſcent of Comets' Tails in a Direction oppoſite to the Sun; I was induced to reconſider his Account of that Matter, which, I own, never appeared ſatisfactory to me; tho' I agree intirely with him that this Phænomenon affords a ſufficient Proof of a *Vacuum* in the Celeſtial Regions. As this is a Subject of ſome Importance in Phyſicks I ſhall, in the following Eſſay, firſt, mention ſuch Objections as occur to me againſt Sir *Iſaac*'s Opinion as to the Cauſe of the Aſcent of Comets' Tails; and then offer ſome Conjectures that may poſſibly lead to a further Knowledge of this Subject, leaving them to be confirmed or overthrown as future Obſervations and Experiments ſhall determine. For I think that Conjectures, or Hypotheſes, when rendered probable by ſome Experiments, and propoſed with Caution, may be of great Uſe by directing our Enquiries into ſome certain Channel.

That I may proceed methodically, I ſhall begin by relating the Phænomena of Comets as obſerved by *Newton*, and other accurate Aſtronomers, for I ſhall have Occaſion to refer frequently to them.

It appears that a Comet is a kind of Planet which revolves round the Sun in a very excentric Orbit, and recedes much farther from the Sun in its *Aphelion* than any of the Planets; it is not viſible until it comes down into the Planetary Regions, and then appears ſurrounded with a denſe

Atmoſphere, and from the Side oppoſite to the Sun it emits a ſhining Train which we call its Tail; this near the Comet is of the ſame Thickneſs or Diameter with the Body, but grows ſomewhat thicker towards the other End. It is at its firſt Appearance very ſhort, and encreaſes as the Comet approaches towards the Sun, and immediately after its *Perihelion* the Tail is longeſt and moſt luminous, and then is generally obſerved to be ſomewhat bent, and to be Convex towards thoſe Parts to which the Comet moves; the Convex Side being rather brighter and better defined than the Concave Side. When the Tail arrives at its greateſt Length which in ſome Comets has been computed to be 60 or 70 Millions of Miles, it quickly decreaſes and ſoon vaniſhes entirely, about the ſame time that the Comet itſelf ceaſes to be ſeen. The Matter of which the Tail is formed is exceedingly rare, and ſo very pellucid that the Light of the ſmalleſt Stars ſuffers no Diminution in paſſing thro' it, for Sir *Iſaac Newton* obſerves: 'The extraordinary Rarity of Comets' Tails may 'be collected from the Stars ſhining thro' them, 'for the ſmalleſt Stars are obſerved to ſhine with'out any loſs of Splendor thro' the Tails which 'are of an immenſe Thickneſs, and are alſo il'luminated by the Light of the Sun.'*

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* Caudarum inſignis raritas colligitur ex Aſtris per eas Tranſlucentibus. — Per Immenſam vero Caudarum Craſſitudi-

Theſe are the principal Phænomena of Comets, and it is from hence we muſt deduce whatever we can know of the Subſtance of which the Tails conſiſt, or of the Reaſon why they are always thrown off from the Head of the Comet, in a Direction nearly oppoſite to the Sun. And with theſe Phænomena I propoſe to compare the Opinions which are commonly received concerning this Matter. Sir *Iſaac* tells us, there were three different Opinions about Comets' Tails; *viz.* that they were only Rays of the Sun propagated thro' the tranſparent Head of the Comet. Or that they aroſe from the Refraction of the Light in its Paſſage from the Head of the Comet to the Earth. Or, laſtly, that they conſiſted of Clouds and Vapours continually riſing from the Head of the Comet, and going off in a Direction oppoſite to the Sun. The firſt and ſecond of theſe Opinions he refutes, and adopts the third, and proves by ſeveral Arguments, that the Tail muſt conſiſt of ſome kind of Vapour ariſing continually from the Head of the Comet. The Cauſe of its aſcending always from the Sun he aſſigns in another Paragraph, which I ſhall

nem, Luce pariter Solis illuſtratam, Aſtra minima abſque Claritatis Detrimento tranſlucere noſcuntur. *Principia,* Page 513. Edit. 2da.

ſhall now quote at length, tranſlating it as faithfully as I can; it is as follows:

‘ The Aſcent of Tails from the Atmoſphere
‘ of Comets and their Progreſs towards the Parts
‘ oppoſite to the Sun, *Kepler* aſcribes to the Action
‘ of the Rays of Light, carrying with them the
‘ Matter of which the Tails conſiſt. And that ſo
‘ very thin an Air or Vapour ſhould yield to the
‘ Action of the Rays, in Spaces void of reſiſtance,
‘ is not altogether againſt Reaſon; altho’ in our
‘ Regions, clogged with reſiſting Matter, the ſolar
‘ Rays cannot ſenſibly impel denſe Bodies. Others
‘ think that there may be ſome Particles of Mat-
‘ ter in their own Nature light, as well as ſome
‘ that are heavy, and that the Matter of the Tails
‘ is of the former Sort, and by its Levity aſcends
‘ from the Sun. But ſince the Gravity of all ter-
‘ reſtial Bodies is proportional to their quantity of
‘ Matter, and cannot in the ſame Body be in-
‘ creaſed or diminiſhed, I ſuſpect that this Aſcent
‘ of the Tails ariſes rather from the Rarefaction
‘ of their Matter. Smoke aſcends in a Chimney
‘ by the Impulſe of the Air in which it floats;
‘ that Air, being rarefied by Heat, and its ſpeci-
‘ fic Gravity thereby diminiſhed, aſcends and
‘ carries the Smoke with it. Why then ſhould
‘ not the Tail of a Comet aſcend in the ſame Man-
‘ ner from the Sun? for the ſolar Rays do not
‘ [illegible]e any Medium thro’ which they paſs, but

‘ in Reflection or Refraction, the reflecting Particles by that Action grow warm, and heat the
‘ ætherial Air (*auram Æthercam*) with which they
‘ are mixed, which being rarefied by this Heat,
‘ and the ſpecific Gravity by which it tended to
‘ the Sun being thereby diminiſhed, it will aſcend
‘ and carry with it the reflecting Particles of which
‘ the Tail is formed: it conduces alſo to the
‘ Aſcent of theſe Vapours that they revolve round
‘ the Sun, and therefore endeavour to recede from
‘ it; while the Atmoſphere of the Sun either is
‘ at reſt, or revolves more ſlowly with ſuch Motion as it can acquire from the Rotation of the
‘ Sun round its Axis. Theſe are the Cauſes of
‘ the Aſcent of the Tails in the Neighbourhood
‘ of the Sun, where the Orbit has a greater Curvature, and the Comet moves in a denſer, and
‘ therefore heavier Atmoſphere of the Sun, and
‘ then emits a Tail of a greater Length. For the
‘ Tails which then ariſe by preſerving their own
‘ Motion, and at the ſame time gravitating towards the Sun, will revolve about the Sun in
‘ *Ellipſes* juſt as their Heads do; and by that Motion will always accompany their Heads and adhere to them moſt freely. For the Gravity of
‘ thoſe Vapours towards the Sun will no more cauſe
‘ the Tails to fall from the Heads to the Sun, than
‘ it will cauſe the Heads to fall from the Tails, but
‘ they muſt both, by their common Gravity, fall
‘ together to the Sun, or both together be retarded
‘ in their Aſcent from it: and conſequently their

‘ Gravity will not hinder the Heads and Tails of
‘ Comets eaſily to receive (from the above-men-
‘ tioned or other Cauſes) any Poſition whatever
‘ in reſpect to each other, or to keep this Poſition
‘ afterwards moſt freely.’§

We find in this Account that Sir *Iſaac* aſcribes the Aſcent of Comets’ Tails to their being rarer and lighter, and moving round the Sun more ſwiftly, than the ſolar Atmoſphere with which he ſuppoſes them to be ſurrounded, whilſt in the Neighbourhood of the Sun; he ſays alſo that whatever Poſition (in reſpect to each other) the Head and Tail of a Comet then receive, they will keep the ſame afterwards moſt freely, and in another Place he obſerves, ‘ that the celeſtial Spaces
‘ muſt be entirely void of any Power of reſiſting,
‘ ſince not only the ſolid Bodies of the Planets
‘ and Comets, but even the exceeding thin Va-
‘ pours, of which Comets’ Tails are formed, move
‘ thro’ thoſe Spaces with immenſe Velocity, and yet
‘ with the greateſt Freedom.’‖—I cannot help thinking that this Account is liable to many Difficulties and Objections, and that it ſeems not very conſiſtent with itſelf or with the Phænomena.

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§ *Principia,* Page 514. ‖ Ibid.

I do not know that we have any Proof of the Exiſtence of a ſolar Atmoſphere of any conſiderable Extent, nor are we any where taught how to gueſs at the Limits of it. It is evident that the Exiſtence of ſuch an Atmoſphere cannot be proved merely by the Aſcent of Comets' Tails from the Sun, as that Phænomenon may poſſibly ariſe from ſome other Cauſe. However let us ſuppoſe, for the preſent, that the Aſcent of Comets' Tails is owing to an Atmoſphere ſurrounding the Sun, and ſee how the Effects ariſing from thence will agree with the Phænomena. When a Comet comes into the ſolar Atmoſphere, and is then deſcending almoſt directly to the Sun, if the Vapours which compoſe the Tail are raiſed up from it by the ſuperior Denſity and Weight of that Atmoſphere, they muſt riſe into thoſe Parts that the Comet has left, and therefore at that time they may appear in a Direction oppoſite to the Sun. But as ſoon as the Comet comes near the Sun, and moves in a Direction nearly at right Angles with the Direction of its Tail, the Vapours which then ariſe, partaking of the great Velocity of the Comet, and being ſpecifically lighter than the *Medium* in which they move, and being vaſtly expanded thro' it, muſt neceſſarily ſuffer a Reſiſtance immenſely greater than what the ſmall and denſe Body of the Comet meets with, and conſequently cannot poſſibly keep up with it, but muſt be driven backwards by the Reſiſtance of that Medium into a Line directed towards the Parts which the Comet has left, and therefore can no longer appear in a Direction oppoſite to the Sun. And in like Manner when a Comet paſſes its *Perihelion*, and begins to aſcend from the Sun, it certainly ought to appear ever after with its Tail behind it, or in a Direction pointed towards the Sun; for if the Tail of the Comet be ſpecifically lighter than the Medium in which it moves with ſo great Velocity, it muſt be juſt as impoſſible it ſhould move foremoſt, as it is that a Torch moved ſwiftly thro' the Air ſhould project its Flame and Smoke before it. Since therefore we find that the Tail of a Comet, even when it is aſcending from the Sun, moves foremoſt and appears in a Direction nearly oppoſite to the Sun, I think we muſt conclude that the Comet and its Tail do not move in a Medium heavier and denſer than the Matter of which the Tail conſiſts, and conſequently that the conſtant Aſcent of the Tail from the Sun muſt be owing to ſome other Cauſe. For that the ſolar Atmoſphere ſhould have Denſity and Weight ſufficient to raiſe up the Vapours of a Comet from the Sun, and yet not be able to give any ſenſible Reſiſtance to theſe Vapours in their rapid Progreſs thro' it, are two things inconſiſtent with each other. And therefore, ſince the Tail of a Comet is found to move as freely as the Body does, we ought rather to conclude that the celeſtial Spaces are void of all reſiſting Matter, than that they are filled with a ſolar Atmoſphere, be it ever ſo rare.

But there is, I think, a further Conſideration which will ſhew that the received Opinion, as to the Aſcent of Comets' Tails, is not agreeable to the Phænomena, and may at the ſame time ſerve to lead us to ſome Knowledge of the Matter of which theſe Tails conſiſt; which I ſuſpect is of a very different Nature from what it has been hitherto ſuppoſed to be. Sir *Iſaac* ſays, the Vapours, of which the Tail of a Comet conſiſts, grow hot by reflecting the Rays of the Sun, and thereby warm and rarefy the Medium which ſurrounds them; which muſt therefore aſcend from the Sun, and carry with it the reflecting Particles of which the Tail is formed; for he always ſpeaks of the Tail as ſhining by reflected Light. But one would rather imagine, from the Phænomena, that the Matter which forms a Comet's Tail has not the leaſt ſenſible Power of reflecting the Rays of Light. And this I think appears from Sir *Iſaac*'s Obſervation which I have quoted already; for he affirms, that the Light of the ſmalleſt Stars, coming to us through the immenſe thickneſs of a Comet's Tail, does not ſuffer the leaſt Diminution. ~~But farther~~ And yet, if the Tail can reflect the Light of the Sun ſo copiouſly, as it muſt do if its great Splendor be derived from thence, it muſt undoubtedly have the ſame Effect on the Light of the Stars; that is, it muſt reflect back the Light, which comes from the Stars behind it, and by ſo doing muſt intercept them from our Sight, conſidering its vaſt thickneſs, and how exceedingly ſlender a Ray is that comes from a ſmall Star, or if it did not intercept their whole Light, it muſt, at leaſt, increaſe their twinkling. But we do not find that it has even this ſmall Effect, for thoſe Stars that appear thro' the Tail are not obſerved to twinkle more than others in their Neighbourhood. Since therefore this Fact is ſupported by Obſervations, what can be a plainer Proof that the Matter of a Comet's Tail has no Power of reflecting the Rays of Light? and conſequently that it muſt be a ſelf-ſhining Subſtance. But the ſame thing will further appear from conſidering that Bodies reflect and refract Light by one and the ſame Power; and therefore if Comets' Tails want the Power of refracting the Rays of Light, they muſt alſo want the Power of reflecting them. Now, that they want this refracting Power appears from hence, if that great Column of tranſparent Matter which forms a Comet's Tail, and moves either in a *Vacuum*, or in ſome Medium of a different Denſity from its own, had any Power of refracting a Ray of Light, coming thro' it from a Star to us, that Ray muſt be turned far out of its way in paſſing over the great

Diſtance between the Comet and the Earth; and, therefore, we ſhould very ſenſibly perceive the ſmalleſt Refraction that the Light of the Stars might ſuffer in paſſing thro' a Comet's Tail. The Conſequence of ſuch a Refraction muſt be very remarkable, the Stars that lie near the Tail would appear double, for they would appear in their proper Places by their direct Rays, and we ſhould ſee their Images behind the Tail, by means of their Rays which it might refract to our Eyes; and thoſe Stars that were really behind the Tail would diſappear, their Rays being turned aſide from us by Refraction. In ſhort, it is eaſy to imagine what ſtrange Alterations would be made in the apparent Places of the fixed Stars by the Tails of Comets, if they had a Power of refracting their Light; which could not fail to be taken Notice of, if any ſuch ever happened. But ſince Aſtronomers have not mentioned any ſuch apparent Changes of Place among the Stars, I take it for granted that the Stars ſeen thro' all Parts of a Comet's Tail appear in their proper Places, and with their uſual Colours, and conſequently I infer that the Rays of Light ſuffer no Refraction in paſſing thro' a Comet's Tail. And thence I conclude (as before) that the Matter of a Comet's Tail has not the Power of refracting or reflecting the Rays of Light, and muſt therefore be a lucid or ſelf-ſhining Subſtance.

And thus if I have argued rightly from the Phænomena, it muſt appear, that the Tail of a Comet does not conſiſt of aqueous or other Vapours, that ſhine by reflecting the Light of the Sun, but is a very rare, tranſparent and lucid Subſtance, which has no ſort of Effect on the Rays of Light that paſs thro' it, and that it is thrown off from the dark Hemiſphere of the Comet in a Direction oppoſite to the Sun, not by the ſuperior Weight and Denſity of any circumambient Medium, but by ſome other Cauſe that has not yet been diſcovered.

This ſeems to me to be all the Knowledge we can acquire of the Nature and Properties of that Matter which form the Tails of Comets, by attending merely to the Phænomenon itſelf. But perhaps we may be able to extend this Knowledge ſomewhat further, if we could find any other Phænomenon in Nature which reſembles this of Comets' Tails, and can become acquainted with any kind of Matter that has the ſame Properties with that of which they are formed. Now I have often obſerved a Phænomenon that, I think, very ſtrongly reſembles the Tail of a Comet, both in its Appearance, and in the Nature of its Subſtance. We frequently ſee a very rare, tranſparent, and lucid Subſtance thrown off, in a Direction nearly oppoſite to the Sun, from the dark Hemiſphere of the Earth, and principally from the more Northern and colder Regions of our Atmoſphere. This Appearance is ſo luminous that it has been from thence called the *Aurora Borealis*; it is now ſo common and well known that I ſhall not deſcribe it particularly, and will only take Notice of thoſe Circumſtances in which it chiefly reſembles a Comet's Tail. Thoſe Northern Lights never appear, at leaſt in any remarkable Degree, ſoon after Sunſet or before Sun-riſe, tho' it may be then dark enough to make them viſible, but generally from about ten o'Clock at Night till one in the Morning; and the very long Streams of Light, which iſſue frequently from the Northern Parts of our Atmoſphere, ſeem ſtill to tend towards the Zenith of that Place where the Spectator is, and ſometimes get beyond the Zenith, and appear to the Southward of it; which ſhews that theſe Streams of Light tend towards the Vertex of the Earth's Shadow, that is, towards the Part of the Heavens which is oppoſite to the Sun. From the great Length of theſe Streams of Light, which ſeem always moving upwards, we may conclude that they extend to a great Height in the Atmoſphere, and probably riſe far above it. For by the Accounts we have of an *Aurora Borealis*, obſerved in *England* on the Sixth of *March*, 1716, it was viſible from the Weſt Side of *Ireland*, to the Confines of *Ruſſia* and *Poland*, and probably farther to the Eaſt; ſo that it extended at leaſt over thirty Degrees of Longitude, and from about the fiftieth Degree of Latitude over almoſt all the North of *Europe*, and at all Places it exhibited the ſame Appearances, nearly at the ſame time.‡

Now this great Body of luminous Matter which appears in an *Aurora Borealis*, being ſo very extenſive and ſometimes ſo very bright, muſt be viſible to a Spectator placed at a conſiderable Diſtance from the Earth, and ſhaded from the Sun's Light; and ſuch a Spectator would then ſee the Earth attended by a Train of Light in the Form of a Tail. It would probably appear ſmall in Proportion to the Earth's Diameter, it would ſeem unſteady, changeable in its Shape, and of a ſhort Continuance; but whilſt it laſted it muſt, both in its Direction, and in the Nature and Appearance of its Light, very much reſemble the Tail of a Comet. And if ſuch a Spectator was to obſerve the Earth for a Year he might perceive a further Reſemblance in this Reſpect between the Earth and a Comet; for as the Tail of a Comet appears only a ſhort time before and after its *Perihelion*, ſo he would ſee this luminous Matter riſe from the Earth frequently whilſt it was moving from the Autumnal to the Vernal Equinox, thro' the half of its Orbit that is neareſt to the

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‡ Philoſ. Tranſ. No. 347.

Sun, and very ſeldom during the other Part of the Year, for we rarely ſee an *Aurora Borealis* in the Summer Months. Thus we find that the Matter of an *Aurora Borealis* and that of a Comet's Tail are very like each other in their Appearance, and in their Situation, with reſpect to the Sun and the Bodies from which they flow. And if we examine further, we ſhall find that they have exactly the ſame Properties; for the Matter of which the *Aurora Borealis* conſiſts is not only very rare, tranſparent and lucid, but is alſo found to have no ſort of Effect on the Rays of Light which paſs thro' it. This I have often obſerved, and particularly at one time when there appeared here an *Aurora Borealis*,† which for its Extent, for the Quantity, Brightneſs and Steadineſs of its Lights, was the moſt remarkable one I ever ſaw; ſome Part of it appeared like very denſe white Clouds, illuminated by a full Moon, but with a more vivid Brightneſs; and yet thro' one of the denſeſt and whiteſt of theſe Clouds, I could plainly ſee the ſmalleſt Star in the *Pliades*, and could not perceive that its Splendour was at all diminiſhed, or that it even twinkled more than it did before this lucid Matter was interpoſed, which, as it moved with a quick tremulous Motion, muſt have at leaſt increaſed the twinkling of the Stars, if it had any ſort of Effect on the Rays which paſſed thro' it. Since then the Matter of a Comet's Tail, and that of the *Aurora Borealis*

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† *October* 16th or 17th, 1763.

Borealis are alike in their Appearance, and agree alſo in their Properties, we have ſome Reaſon to ſuppoſe that they are Subſtances of the ſame Kind.

Having gained this Step, we may go on in our Enquiries, and try if any other Subſtance, that we are better acquainted with, has the ſame Properties with the Subſtance of which Comets' Tails and the *Aurora Borealis* are formed. It is now well known that our Atmoſphere abounds with electric Matter, which is more or leſs contained in all Bodies; this Matter is never viſible but whilſt it is paſſing from one Body to another, thro' the Air or a Vacuum, it then appears to be a very rare, ſubtle, ſhining Subſtance. We often ſee it flaſhing from one Cloud to another, or into the Earth, with great Velocity and Brightneſs, and then we give it the Name of Lightning; and in the ſame Manner when we bring our Finger near a Bar of Iron ſtrongly electrified, we ſee very bright Sparks iſſue from it to our Finger. It ſeems that Air, in its common State of Condenſation, reſiſts the Egreſs of the electric Matter from Bodies in which it is accumulated, eſpecially if they are round and ſmooth, and when it forces its Way it ſeems to come out, as it were, all at once, and in a very condenſed State, and therefore it appears very bright. But if the Air be conſiderably rarefied its Reſiſtance is thereby greatly leſſened, and the electric Matter cannot be accumulated in a Body ſurrounded by ſuch Air, for in that Caſe, as faſt as it is communicated to the Body it will iſſue out from various Parts of it in ſmall Streams of a faint Light, as will appear from ſome Experiments I ſhall have Occaſion to mention preſently.

Now ſince a ſolid Body and a Cloud, when electrified in denſe Air, will both diſcharge their Fire in the ſame Manner, that is, ſuddenly and in bright Sparks, or large bright Flaſhes, we muſt conclude, from Analogy, that when they are both electrified in Air much rarefied, they will then likewiſe diſcharge their Fire in the ſame Manner, and conſequently that an electrified Cloud, raiſed into the higher and rarer Parts of the Atmoſphere, will diſcharge its Fire in continued Streams of faint Light. And as we ſometimes ſee faint flaſhes of Lightning in a Summer Evening after Sun-ſet, tho' no Clouds appear; ſo if the Vapours which riſe into the higher Part of the Atmoſphere, tho' not formed into Clouds, carry up with them the electric Matter, they muſt diſcharge it in continued Streams of faint Light, juſt as a Cloud would do; and thoſe Streams of Light in the higher Parts of the Atmoſphere muſt exactly repreſent to us the Appearance of an *Aurora Borealis*. Any one will readily perceive a ſtrong Reſemblance between the *Au-*

rora Borealis and the electric Fire diſcharged from a Body in rarefied Air, who will make the following Experiments.

Let the Air be almoſt exhauſted out of a Glaſs Globe or Cylinder, and let it be turned by a Machine and rubbed as uſual; the electric Fire will then appear in the Inſide of the Globe, ſhooting out in various Branches of faint Light, croſſing each other in all Directions, and this Light will ſometimes appear tinged with different Colours; when the Air is very much rarefied the Light appears white, and grows more of a purple Colour as more Air is admitted into the Globe. I found this Experiment ſucceed beſt when I held in my Hand the Cuſhion with which the Globe was rubbed, and preſſed it ſometimes cloſely and ſometimes ſlightly to the Globe. I made alſo another Experiment to the ſame Purpoſe. A Cylinder 20 Inches high, and about 5 in diameter, having a pretty thick Braſs Wire put thro' the Top, was almoſt exhauſted, then being myſelf electrified, I moved my Finger towards the Top of the Wire, and immediately I ſaw every Spark that came from my Finger divided into a Multitude of ſmall Streams of Light iſſuing from the Wire at right Angles to it, and in different Directions. When I took hold of the Wire I could ſee but little Light in the Cylinder, ſo found it was neceſſary to keep my Finger at a ſmall Diſtance, and let the electric Matter come to the Wire in ſucceſſive Sparks. I thought the Lights that iſſued from the Wire were brighteſt when it was oyled, and when the Air was about 30 times rarer than the outward Air. Several Perſons almoſt as ſoon as they ſaw the electric Lights compared them to the Appearance of the *Aurora Borealis*; and certainly theſe two Phænomena reſemble each other entirely both in the Colours of their Light, and in the Quickneſs of their Motions. For when the Air in the Glaſs-Globe was very much rarefied, the electric Lights appeared very white, and became more of a purple Colour as more Air was admitted into the Globe; juſt ſo the long Streams of Light in the *Aurora Borealis* are very white on their upper Parts where the Air about them is much rarefied, and are often of a purple Colour on their lower Parts which are in denſer Air. And as in the Globe the electric Lights appear in greater Abundance when the Air has a particular Degree of Denſity than in other Caſes; ſo the quick Appearing and Diſappearing of the Streams of Light in the *Aurora Borealis* may poſſibly ariſe from a Charge of Denſity in the higher Parts of the Atmoſphere. For where the Air is ſo very thin it may be ſubject to very ſudden Condenſations, Rarefactions occaſioned by the Motion of the Winds, and I have obſerved thoſe Lights to be more unſteady in a windy Night than when it was calm.

But the electric Matter appears to be of the ſame kind of Subſtance which forms the *Aurora Borealis*, and the Tails of Comets, by its having alſo that remarkable Property of letting the Rays of Light paſs thro' it, without having any ſort of Effect upon them. And this I found by ſeveral Experiments; for I obſerved that ſmall Rays of Light, paſſing over ſharp Points, and by the Edges of Knives, from whence the electric Matter iſſued abundantly, were affected in the very ſame Manner as when theſe Points and Edges were not electrified. Having provided a large Pane of Glaſs properly coated on both Sides with thin ſheet Lead, I made two ſmall Holes in the Lead, oppoſite to each other, for a Ray of Light to paſs thro'; and I found this Ray was no more refracted in its Paſſage thro' the Holes, when one Side of the Glaſs was electrified *Plus*, and the other *Minus*, than it was before the Glaſs was electrified at all, or after the electric Matter was diſcharged, which ſhews that the Accumulation, or the Abſence of this Matter no way contributed to encreaſe or diminiſh the refractive Power of the Glaſs. I found that when Water was electrified no change was made either in its Power of refracting or reflecting the Rays of Light.

I made many other Experiments of the ſame kind, too tedious to deſcribe, and they all led me to conclude that the electric Matter had no ſort of Effect on the Rays of Light that paſſed thro' it. Since then the electric Matter ſeems to be of the ſame Nature with that which forms the *Aurora Borealis*, and abounds much in the Atmoſphere, and, when it gets into the rarer Parts of it, will, by its known Properties, exhibit to us an Appearance like that of the *Aurora Borealis*, we muſt acknowledge it to be a Cauſe really exiſting, and ſufficient to explain this Phænomenon, and therefore we may aſcribe the Appearance of an *Aurora Borealis* to the Riſing of the electric Matter into the upper Regions of the Atmoſphere. The following Obſervation will ſerve further to confirm this Opinion. In our Summer Months, when the electric Matter is frequently diſcharged from the lower Clouds in Lightning, and ſo returns to the Earth, we ſcarce ever ſee an *Aurora Borealis*; but at other times, when it is not uſually diſcharged in Lightning, it may riſe higher into the Atmoſphere, and will occaſion more frequent Appearances of this kind. And this probably is the Reaſon why theſe Appearances are more frequent in cold than in warm Climates, the former being leſs ſubject to Storms of Thunder and Lightning than the latter. In Countries that lie far to the North the *Aurora Borealis* is ſaid to ſhine much brighter than with us, and to appear almoſt every Night.

As the preceding Conſiderations ſeem to make it probable that the Tails of Comets conſiſt of the ſame kind of Subſtance which forms the *Aurora Borealis*, and that this is no other than the electric Matter; I ſhall aſſume this as a Principle, and try if I can from thence Account, in ſome Meaſure, for the Phænomenon of Comets' Tails, and in doing this I ſhall have an Opportunity of making ſome Obſervations which may ſerve to ſhew a further Reſemblance between thoſe three Subſtances that I have compared together. The Earth, and all Bodies near it, contain more or leſs of the electric Matter, and tho' it may be accumulated in ſome Bodies, and diminiſhed in others, we cannot be ſure that any Body may be totally deprived of it, but on the Contrary have great Reaſon to think it can neither be increaſed nor diminiſhed in any Body beyond a certain Degree; we muſt therefore ſuppoſe that it is contained in all Bodies in our ſolar Syſtem. Some Bodies ſuch as Glaſs, Amber and others, that are called *Electrics*, attract and retain this Matter more ſtrongly than thoſe do which are called *Non-Electrics*, for an electric Body will draw this Matter from one that is not electric againſt which it is rubbed, and it will alſo ſtop the electric Matter in its Progreſs from one Body to another, and therefore an electric Body is called a *Non-conductor*, in Oppoſition to other Bodies thro' which the electric Matter readily paſſes. But we find that any Body even the moſt Electric, if ſufficiently heated, will become a *Conductor*, or will let the electric Matter paſs from it very eaſily, and therefore we conclude that Heat diſpoſes all Bodies readily to part with the electric Matter they contain, and we have an Inſtance in the *Tourmalin* Stone that ſome Bodies will always throw off an electric Matter merely by being heated. Now when a Comet comes down towards the Sun, from Regions of extreme Cold, and begins to acquire ſome Degree of Heat, it will, like other Bodies, be diſpoſed to part with the electric Matter, which it may poſſibly contain in great Abundance, and this Matter, when thrown off, will exhibit to us the Appearance of a ſhining Train, as it does in the *Aurora Borealis*; and as the Comet comes to its *Perihelion*, and the Heat increaſes, this Matter will iſſue more abundantly, and the Train or Tail will increaſe in Length, till upon the Comets' receding from the Sun the Heat will decreaſe, and this Matter being pretty much exhauſted, the Tail will be contracted in its

Dimenſions, and at length will be too far removed, and grow too faint to be obſerved.

As a Comet is expoſed to vaſt extremes of Heat and Cold, Light and Darkneſs, we may well ſuppoſe it to be uninhabited, and if ſo it is not neceſſary that it ſhould turn round its Axis, but may always keep the ſame Face towards the Sun, as the Moon keeps the ſame Face towards the Earth, and indeed it muſt do ſo if its Figure be that of an oblong Spheroid. Now the electric Matter which riſes from the Earth goes off into the colder Regions of the Atmoſphere, and in a Direction nearly oppoſite to the Sun, and I believe we have no Inſtance of what we call the *Aurora Borealis* appearing between the Tropicks. Why then ſhould not this Matter take the ſame Courſe in its Progreſs from the Head of the Comet, and fly off from its dark Hemiſphere, where its Atmoſphere is colder and clearer, and where the Vapours are thin, and, riſing more gradually, will give it an Opportunity of riſing along with them; whilſt on the other Hemiſphere, which is expoſed to the Sun, the Vapours muſt riſe very thick, and form Clouds which may intercept the electric Matter in its Progreſs, and collecting it together may return it back to the Head of the Comet in Lightning as our Clouds in hot Countries return their electric Matter into the Earth. Beſides as we find that the electric Matter paſſes off from a Body where it is rough or pointed much more readily than where it is round and ſmooth, ſo it is poſſible that the Hemiſphere of the Comet, which is turned from the Sun, may be ſo formed as to part with the electric Matter more readily than the other, which is turned towards the Sun; and in whatever Direction the electric Matter is thrown off from any Body we find it continues to move with immenſe Velocity, as I obſerved in the Streams of electric Matter which iſſued from the Wire in the exhauſted Receiver. I obſerved alſo that theſe Streams did not grow much thicker as they advanced in their Courſe, either in the exhauſted Globe or cylindrical Receiver; nor did they ſeem diſpoſed to expand themſelves into the Space that ſurrounded them, but went ſtraight forward juſt as a Ray of ſolar Light would do. And thus the Matter which iſſues from a Comet proceeds in the ſame Direction in which it is thrown off, and forms that large Column, which we call the Tail; and we ſee that the Matter of which the Tail conſiſts has very little or no Diſpoſition to expand itſelf into the ſurrounding Spaces; for the Tail is not much broader towards the End than near the Head of the Comet. This I think is a moſt extraordinary Property, both of the electric Matter, and of that which forms a Comet's Tail, and which is a further Argument for concluding them to be of the ſame Nature, for they both fly off from the Body, in which they are, with great Velocity, which ſeems to argue a repulſive and expanſive Force, yet they proceed as the Rays of Light do without expanding themſelves laterally into the Spaces thro' which they paſs.

And this remarkable Property ſeems well worth attending to in all our Enquiries concerning the electric Matter. At preſent we are ſo little acquainted with the true Nature of it, and ſo ignorant of the Subſtance which forms the Body of the Comet, that is not to be expected, we ſhould be able to ſay how it can furniſh ſuch a vaſt Quantity of this electric Matter, or to aſſign with Certainty the Reaſon why the Tail of a Comet is thrown off from its dark Hemiſphere in a Direction oppoſite to the Sun, rather than in any other Direction. Future Experiments and Obſervations will either confirm theſe Conjectures of mine or ſuggeſt others more probable; but now we can only argue by Analogy from the riſing of the electric Matter thro' the colder Regions of our Atmoſphere in the *Aurora Borealis*, that the ſame Effect will take Place in the Atmoſphere of a Comet, and from the ſame Cauſe, whatever that may be.

Sir *Iſaac Newton* obſerves the Tail of the Comet which came to its *Perihelion* on the eighth of *December*, 1680, appeared about the Middle of *January* following to be bent into a Curve. Now as the Tail was convex towards thoſe Parts to which the Comet moved, this bending might ſeem to ariſe from its meeting with ſome reſiſting Matter; but this Curvature was much leſs than what would ariſe from a reſiſting Matter denſer than the Tail, and whoſe ſuperior Gravity would be able to raiſe it up from the Sun; for he tells us that on the 5th of *January* when the Tail was 40 Degrees long, its Chord, or a Line drawn from the Head of the Comet to the Extremity of its Tail, made an Angle of only 8 Degrees with a great Circle paſſing thro' the Sun and Comet. But that this Curvature was not owing to any reſiſting Matter appears from hence, that the Tail muſt be bent into a Curve tho' it met with no Reſiſtance; for it could not be a right Line unleſs all its Particles were projected in the ſame Direction, and with the ſame Velocity, and unleſs the Comet moved uniformly in a right Line. But the Comet moves in a Curve, and each Part of the Tail is projected in a Direction oppoſite to the Sun, and at the ſame time partakes of the Motion of the Comet; ſo that the different Parts of the Tail muſt move on in Lines which diverge from each other; and a Line drawn from the Head of a Comet to the

Extremity of the Tail will be parallel to a Line drawn from the Sun to the Place where the Comet was, when that Part of the Tail began to aſcend, as Sir *Iſaac* obſerves; and ſo all the Chords, or Lines drawn from the Head of the Comet to the intermediate Parts of the Tail, will be reſpectively parallel to Lines drawn from the Sun to the Places where the Comet was when theſe Parts of the Tail began to aſcend. And therefore ſince theſe Chords of the Tail will be of different Lengths, and parallel to different Lines, they muſt make different Angles, with a great Circle paſſing thro' the Sun and Comet, and conſequently a Line paſſing thro' their Extremities will be a Curve.

It is obſerved that the convex Side of the Tail which is turned from the Sun is better defined and ſhines a little brighter than the concave Side. Sir *Iſaac* accounts for this by ſaying, that the Vapour on the convex Side is freſher (that is, has aſcended later) than that on the concave Side, and yet I cannot ſee how the Particles on the convex Side can be thought to have aſcended later than thoſe on the concave Side which may be nearer to the Head of the Comet. I think it rather looks as if the Tail, in its rapid Motion, met with ſome ſlight Reſiſtance juſt ſufficient to cauſe a ſmall Condenſation in that Side of it which moves foremoſt, and which would occaſion it to appear a little brighter and better defined than the other Side; which ſlight Reſiſtance may ariſe from that ſubtle Æther which is ſuppoſed to be diſperſed thro' the celeſtial Regions, or from this very electric Matter diſperſed in the ſame Manner, if it be different from the Æther. Here I muſt obſerve that the convex Side of the Tail, which is turned from the Sun, being brighter than the other Side, affords an additional Argument in favour of what I have aſſerted, that the Tail does not ſhine by reflecting the Sun's Light. And this leads me to ſay ſomething of that luminous Quality which we obſerve in the electric Matter, and by which I ſuppoſe the Tails of Comets to ſhine.

The Writers on Electricity tell us that the electric Matter carries off from Bodies certain ſubtile Particles of a ſulphurous inflammable Nature, which it kindles as ſoon as they are diſengaged from the Body, and thence it ſhines. And this Account is proved from its inflaming other Bodies, ſuch as warm Spirits, and from that ſulphurous Smell which always attends the electric Matter, and which, any one will perceive from his Hand, if he receives the electric Sparks on it for ſome time, and the ſame Smell is more ſtrongly perceived in Places that have been ſtruck by Lightning. Now theſe inflammable Vapours which often abound in the Air, being carried up by the electric Matter, and kindled in the higher Parts of the Atmoſphere, will cauſe it to ſhine and appear to us in the *Aurora Borealis.*

But perhaps it may be ſaid, that, without having recourſe to the electric Matter, we might ſuppoſe the Comet, or a great Part of it, to conſiſt of ſome very combuſtible Matter which may take fire by a ſmall Degree of Heat, and blaze out in ſuch Abundance as to occaſion that luminous Appearance we call the Tail. And this Hypotheſis may appear at firſt Sight more natural and probable than the one I have ſuggeſted; yet I imagine it will not be found ſo, if we examine it attentively. For if the Comet were to take fire and blaze out as burning Bodies do with us, the elaſticity of the Flame might indeed raiſe it to ſome Diſtance from the Body of the Comet, but then it would riſe equally on all Sides, or rather to a greater Height on the Side next the Sun, where the Heat is greateſt. And a Flame of this kind could not be carried up in a Direction oppoſite to the Sun, unleſs it were by the ſuperior Denſity and Weight of ſome ſurrounding Medium which gravitates towards the Sun; juſt as we find the Flame of burning Bodies is raiſed upwards by the Preſſure of the ſurrounding Air. But I have ſhewn, in the former Part of this Eſſay, that a Medium denſer and heavier than the Tail muſt reſiſt and retard its Motion much more than that of the Comet, and therefore could never permit the Tail to move foremoſt as it ſometimes does, but muſt cauſe it always to fall behind, and conſequently to appear as directed towards the Sun when the Comet has paſſed its *Perihelion*, and is retiring from the Sun. So that in order to account for the conſtant Aſcent of this luminous Matter in a Direction oppoſite to the Sun, we muſt have recourſe to ſome Medium that has no ſenſible Gravity, and that is apt to move in ſome particular Direction from the Body in which it is, and with ſuch Velocity as to carry the burning Matter to a vaſt Diſtance from the Comet before it is entirely conſumed. Now I believe we do not know of any Medium that has theſe Properties except that which we call the electric Matter. For it ſeems no more affected by the Force of Gravity than the Rays of Light are, and when it moves freely it is apt to go on in the Direction in which it ſets out, as I obſerved before, and then it moves with ſuch a Velocity as we cannot meaſure. For it has been found to paſs thro' a Wire two Miles and a Half in Length, as it were, inſtantaneouſly, and probably its Velocity is not inferior to that of the Rays of Light. This Medium therefore ſeems not only capable of kindling ſuch ſubtile inflammable Particles as it meets with in the Comet, but alſo of carrying them off, before they are conſumed, to that vaſt Diſtance to which the Tail ſometimes extends.

Where the inflammable Particles are quite conſumed, the Tail of the Comet muſt end; and the electric Matter will afterwards be inviſibly diſperſed thro' the planetary Regions, where it may be gathered up by the Planets in their Courſes round the Sun. For ſince we find this kind of Matter placed in all Bodies by the Wiſdom of Providence, we muſt conclude it is neceſſary for carrying on the ſeveral Operations of Nature; and we know it is very apt to eſcape from Bodies by its great Subtilty and repelling Force. We ſee it riſes from the Earth into the Atmoſphere, and is probably going off from thence when it appears in the *Aurora Borealis*. In like Manner it may fly off from the other Planets, and be continually expanding itſelf from the Center of our Syſtem beyond the Orbit of *Saturn*. So that it may be neceſſary it ſhould be brought back again and diſperſed among us by the Comets. And it ſeems to me more probable that Comets were intended for this Uſe, than for that of ſupplying the Planets with Moiſture, as Sir *Iſaac Newton* thought. His Opinion was founded on a Suppoſition that all Vegetables have their Growth and Increaſe entirely from Water, and that ſince they do not turn again into Water but into Earth, there muſt be a continual Decay of Moiſture, and therefore a freſh Supply of it muſt be neceſſary from time to time.* But this Suppoſition does not ſeem to have been ſufficiently grounded on Experience. For, ſince Sir *Iſaac* wrote, Dr. *Woodward*, an ingenious Phyſician, made ſeveral Experiments on Water and Vegetables growing from it. He ſhews that all Water contains an earthy Matter, and concludes: ‘ It is evident therefore, that Water ‘ is not the Matter that compoſes vegetable Bodies; ‘ but is the Agent that conveys that Matter ‘ to them, that introduces, and diſtributes ‘ it to the ſeveral Parts for their Nouriſh‘ ment. Where the proper terreſtrial Matter ‘ is wanting, the Plant is not augmented tho’ ‘ never ſo much Water aſcends into it.’† This is alſo the Opinion of Dr. *Boerhaave*, and he affirms from his own Experience, that pure elementary Water cannot, by repeated Diſtillations, or otherwiſe, be converted into Earth.‡ So that there ſeems to be no Neceſſity for ſuppoſing a gradual Decay of Moiſture in any of the Planets. Beſides, if the Comets were intended to ſupply the Planets with Moiſture, none of them could ſerve for this Purpoſe more than once, but muſt afterwards become uſeleſs, tho' they return regularly in their Orbits, which is not agreeable to the Oeconomy of Nature. For when the Heat of the Sun had driven all the Moiſture it could from a Comet in its *Perihelion*, where ſhould it afterwards get a freſh Supply? We can ſcarce ſuppoſe the Planets to loſe any Moiſture by Evaporation, as no Vapours can riſe above their Atmoſpheres. Or even if any very thin Vapours, Steams or Effluvia of a moiſt Nature ſhould ariſe from them, they could not have Heat and Elaſticity enough to expand themſelves very far. But the electric Matter, from its vaſt ſubtilty and velocity, ſeems capable of making great Excurſions from the planetary Syſtem, and therefore the ſeveral Comets in their long excurſions from the Sun, in all Directions, may overtake this Matter; and attracting it to themſelves may come back replete with it, and being again heated by the Sun may diſperſe it among the Planets, and ſo keep up a Circulation of this Matter which we have reaſon to think it neceſſary in our Syſtem.

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* Nam Vegetabilia omnia ex Liquoribus *omnino* creſcunt, dein magna ex parte in Terram aridam per Putrefactionem abeunt, & Limus ex Liquoribus putrefactis perpetuo decidit. Hinc moles Terræ aridæ indies augetur, & Liquores, niſi aliunde augmentum ſumerent, perpetuo decreſcere deberent, ac tandem deficere. *Principia,* Pag. 515. Edit. 2da.

† *Philoſ. Tranſactions.* No. 253.

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‡ *Elements of Chymiſtry*, Part 2d.

Sir *Iſaac*, after giving his Opinion that the aqueous Particles thrown off from Comets are taken up by the Planets as a ſupply of Moiſture, adds: ‘ I ſuſpect moreover, That that Spirit which is the ‘ leaſt, but the moſt ſubtile and the beſt Part of ‘ our Air, and is neceſſary for ſupporting the Life ‘ of all Things, comes chiefly from the Comets.’‡ which ſhews that he thought the Tails of Comets conſiſted of ſomething more than watery Clouds and Vapours. What he meant by theſe Words I cannot ſay with Certainty, but I think they are extremely applicable to that kind of Matter which I have ſuppoſed comes to us from the Comets; and with which our Air generally abounds.

I ſhall now recapitulate, in a few Words, the Subſtance of what has been ſaid. As the Tail of a Comet, tho' exceedingly rare, yet meets with no Reſiſtance in its rapid Motion round the Sun, (except ſo ſlight a one as can only cauſe a very ſmall Condenſation on that Side of it which moves foremoſt, and thereby may make it a little brighter than the other Side) it cannot poſſibly move in a *Medium* denſer and heavier than itſelf, and therefore cannot be raiſed up from the Sun by the ſuperior Gravity of ſuch a *Medium.* And ſince the Tail is not capable of reflecting or refracting the Light of the Stars, it cannot ſhine by reflecting the Sun's Light; and conſequently does not conſiſt of Clouds or aqueous Vapours, but is itſelf a ſhining Subſtance. And from what Aſtronomers ſay of the Splendor of Comets' Tails, I am perſuaded they do not ſhine with ſuch a dull Light, as would be reflected to us by Clouds or Vapours at ſo great a Diſtance, but with a briſker, tho' a glimmering Light, ſuch as would ariſe from a very thin volatile burning Matter. And here I muſt not omit an Obſervation of Dr. *Halley*'s, which ſeems very much to my Purpoſe. In his Deſcription of the remarkable *Aurora Borealis* ſeen in *England* in the Year 1716, (which I mentioned before) ſpeaking of the great Streams of Light, he ſays: *They ſo much reſembled the long Tails of Comets, that at firſt Sight they might well be taken for ſuch.* And afterwards, *This Light ſeems to have a great Affinity to that which the Effluvia of electric Bodies emit in the Dark.*§ From whence we find that this accurate Obſerver perceived a Reſemblance between thoſe Subſtances that I have been comparing together. Now I have ſhewn that they agree remarkably, not only in their Appearance, but alſo in ſuch Properties as we can obſerve in each of them, and therefore I have ſuppoſed them to be Subſtances of the ſame Nature. I have alſo endeavoured to ſhew that the electric Matter, from its known Properties, is capable of exhibiting to us all the Phænomena of Comets' Tails, and that we may from thence aſſign the Uſe of Comets with more Probability than has hitherto been done. By this Account, if it ſhould happen to be a true one, we ſhall avoid all thoſe Objections that have been made to the *Newtonian* Doctrine of a *Vacuum* in the celeſtial Spaces, from the Aſcent and Bending of Comets' Tails. For the electric Matter is far too rare and ſubtile to give any Reſiſtance to the Motion of large and denſe Bodies, as we find it paſſes thro' them with as much Eaſe as thro' a Vacuum. And theſe Obſervations, by tending to ſhew the Univerſality of this kind of Matter, may encourage us to further Enquiries into its Nature and Properties; from a Knowledge of which I ſuſpect our future Improvements in Natural Philoſophy will chiefly ariſe; eſpecially in that Part of it which relates to Fire and Heat, the Nature of which is at preſent but little known.

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‡ Porro ſuſpicor Spiritum illum qui Aeris noſtri pars minima eſt, ſed ſubtiliſſima & optima, & ad rerum omnium vitam requiritur ex Cometis præcipue venire. *Principia,* Pag. 515.

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§ *Philoſ. Tranſactions*, No. 347.

FINIS.